





## Unclassified

security classification of this page

## REPORT DOCUMENTATION PAGE

1a Report Security Classification Unclassified		1b Restrictive Markings			
2a Security Classification Authority		3 Distribution Availability of Report Approved for public release; distribution is unlimited.			
2b Declassification/Downgrading Schedule					
4 Performing Organization Report Number(s)		5 Monitoring Organization Report Number(s)			
6a Name of Performing Organization Naval Postgraduate School	6b Office Symbol (if applicable) 570	7a Name of Monitoring Organization Naval Postgraduate School			
6c Address (city, state, and ZIP code) Monterey, CA 93943-5000		7b Address (city, state, and ZIP code) Monterey, CA 93943-5000			
8a Name of Funding Sponsoring Organization	8b Office Symbol (if applicable)	9 Procurement Instrument Identification Number			
8c Address (city, state, and ZIP code)		10 Source of Funding Numbers			
		Program Element No	Project No	Task No	Work Unit Accession No
11 Title (include security classification) NUMERICAL FIELD MODEL SIMULATION OF FIRE AND HEAT TRANSFER IN A RECTANGULAR COMPARTMENT					
12 Personal Author(s) Kenneth J. Thorkildsen					
13a Type of Report Master's Thesis	13b Time Covered From	To	14 Date of Report (year, month, day) September 1992	15 Page Count 195	

16 Supplementary Notation The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17 Cosat: Codes	18 Subject Terms (continue on reverse if necessary and identify by block number) Fire modeling, compartment fire simulation, computer modeling	
Field	Group	Subgroup

19 Abstract (continue on reverse if necessary and identify by block number)  
Shipboard fires have been the bane of mariners since man's earliest attempts to sail the sea. Understanding the behavior of fire in an enclosed space, such as those found on today's modern seagoing vessels, will greatly enhance the mariner's ability to combat or prevent them. In a joint effort between the Naval Postgraduate School and the University of Notre Dame, a computer code has been developed to model a full scale fire in a closed compartment. The code uses a finite volume formulation to obtain numerical solutions to the unsteady, three dimensional conservation equations of mass, momentum and energy. Included are the effects of turbulence, strong buoyancy, surface radiation and wall conduction. The code gives velocities, pressure, temperatures, and densities throughout the field.

This thesis applies that computer code to the U.S. Navy's full scale fire test chamber at Naval Air Warfare Center, China Lake, California. Advanced computer graphics techniques, including color contouring and three dimensional vector field plotting have been applied to make output data more informative. It is hoped that someday this model could provide a useful tool for naval architects in the design of a fire safe ship, and a cost effective means for development/evaluation of new firefighting equipment and techniques.

20 Distribution Availability of Abstract <input checked="" type="checkbox"/> unclassified/unlimited <input type="checkbox"/> same as report <input type="checkbox"/> DTIC users	21 Abstract Security Classification Unclassified	
22a Name of Responsible Individual M.D. Kelleher	22b Telephone (include Area code) (408) 646-2530	22c Office Symbol ME/kk

DD FORM 1473,84 MAR

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Numerical Field Model Simulation  
of  
Fire and Heat Transfer  
in a Rectangular Compartment

by

Kenneth J. Thorkildsen  
Lieutenant, United States Coast Guard  
B.S., United States Coast Guard Academy, 1980

Submitted in partial fulfillment of the  
requirements for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL  
September 1992

## ABSTRACT

Shipboard fires have been the bane of mariners since man's earliest attempts to sail the sea. Understanding the behavior of fire in an enclosed space, such as those found on today's modern seagoing vessels, will greatly enhance the mariner's ability to combat or prevent them. In a joint effort between the Naval Postgraduate School and the University of Notre Dame a computer code has been developed to model a full scale fire in a closed compartment. The code uses a finite volume formulation to obtain numerical solutions to the unsteady, three dimensional conservation equations of mass, momentum and energy. Included are the effects of turbulence, strong buoyancy, surface radiation and wall conduction. The code gives velocities, pressure, temperatures, and densities throughout the field.

This thesis applies that computer code to the U.S. Navy's full scale fire test chamber at Naval Air Warfare Center, China Lake, California. Advanced computer graphics techniques, including color contouring and three dimensional vector field plotting have been applied to make output data more informative. It is hoped that someday this model could provide a useful tool for naval architects in the design of a fire safe ship, and a cost effective means for development/evaluation of new firefighting equipment and techniques.

## THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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## **ACKNOWLEDGEMENTS**

The author would like to take this opportunity to thank the following persons for their contributions to this work:

To Professor K.T. Yang of the University of Notre Dame, for providing the program FIRE which is central to this work and for making himself available whenever there were questions regarding the code.

To Mr. Kent Farmer of the Naval Air Warfare Center, China Lake, CA for providing the data regarding the fire test chamber.

To Dr. Devadatta Mukutmoni of the Naval Postgraduate School whose assistance with development of the plotting programs and troubleshooting all of the programs was instrumental in completion of this work.



## I. INTRODUCTION

### A. BACKGROUND

Fire aboard ship is one of the professional mariner's worst fears. With no place to go to escape the heat and smoke the mariner must fight the blaze or face the loss of his vessel. Even though U.S. merchant marine and naval personnel receive some of the best fire fighting training available, annual losses to shipboard fires can easily run into the hundred million dollar range. Ship down time, equipment repair/replacement, personnel injuries and casualties all contribute to these costs and result in the degradation of our merchant marine and naval forces. To minimize these losses it is imperative that the phenomena of fire be studied and understood especially in the relatively closed environment found aboard ship. It is only through study and understanding that adequate means may be developed to prevent or mitigate the devastating effects of a shipboard fire.

Fire is a complex phenomena whose study is equally complex, requiring the combined knowledge of a variety of fields including fluid dynamics, heat and mass transfer, and combustion. Research into the mechanics of fire and development of methods to predict its behavior will aid engineers in reducing the probability of its ignition and minimizing its effects once ignited. [Ref. 1]

It is the complexity of fire which makes its study so difficult, especially in a shipboard environment. Small scale fire studies have proven inadequate for predicting the behavior of large scale fires. Therefore, full scale studies are generally the only means for conducting realistic experimentation. However, such full scale experimentation can be very costly and dangerous. Shipboard fires often occur in fully enclosed, airtight spaces where pressures can build up during the fire. These spaces may have restricted accesses, contain electronic equipment, flammables and/or toxics, all of which add to the expense and danger of full scale experimentation. Additional costs will also be incurred as air quality and emission standards are stiffened across the country.

To study the phenomena of shipboard fire, the U.S. Navy has built a test facility at the Naval Research Laboratory in Washington, DC known as Fire-1. This facility is essentially a large cylindrical pressure vessel with spherical endcaps intended for use in full scale modeling of fires inside submarines and/or in closed airtight compartments aboard ships. Missile attacks against British warships during the Falklands crisis and the

Iraqi missile attack on the USS STARK in the Persian Gulf in 1987 prompted the U.S. Navy to build a second fire test facility at the Naval Air Warfare Center (NAWC) in China Lake, CA. The purpose of this facility is to study the effects of fire in a vented compartment [Ref. 2, pp. 7-8]. It is this facility which is modeled in this thesis.

A less expensive, and less dangerous alternative to full scale fire experimentation is the use of computer modeling techniques. The development of high speed, high capacity computers has allowed researchers to model thoroughly the complex fire phenomena and predict fire behavior without the expense of full scale testing. A properly developed computer model, validated against actual full scale test data, can provide a less expensive and safe alternative to full scale experimentation. Furthermore, the inherent flexibility of computer modeling allows it to be used on increasingly more complex geometries. Someday this may lead to modeling of entire ships during the design phase to identify areas particularly susceptible to fire, or for the accurate prediction of the effectiveness of new firefighting techniques.

## B. COMPUTER MODELING

Field modeling uses finite difference techniques to subdivide the volume being studied, in this case the simulated shipboard compartment, into small, finite volume elements. Using initial conditions specified by the user and the finite difference forms of the equations for conservation of mass, momentum, and energy, values of temperature, pressure, velocity and density are calculated for each of the individual volumetric elements at discrete time intervals. Additional modeling of physical effects such as radiation, turbulence and wall conduction are included to increase the validity of the simulation. The enormous number of calculations necessary for this type of modeling mandates the use of large amounts of computer memory and high speed processors.

The basis for this thesis is provided by a large number of previous research projects. One of the earliest successful models of this type was developed by Aziz and Hellums [Ref. 3] at Rice University in Houston, Texas. They expressed the Navier-Stokes equations in terms of vorticity and vector potential, then solved the resulting three dimensional finite difference equations using a combination of the alternating direction method and successive over-relaxation (SOR). Later work by Mallinson and de Vahl Davis [Ref. 4], Morrison and Tran [Ref. 5]; Chan and Banerjee [Ref. 6]; Ozeo, Fujii, Lior and Churchill [Ref. 7]; and a host of others have all expanded on the use of finite difference techniques to model convective heat transfer in closed compartments.

In the late 1970's and early 1980's, R.G. Rehm and H.R. Baum began developing equations to describe the buoyant flow induced by large scale fires [Refs. 8, 9, 10 and 11]. Work done at the University of Notre Dame used a two dimensional finite difference field model to predict velocities, temperatures and smoke concentrations in aircraft cabin fires [Ref. 12 and 13]. The development of a two dimensional model of transient, natural convection cooling was developed, and experimentally verified, by Nicolette *et al* [Ref. 14] using a semi-implicit upwind differencing scheme and global pressure corrections. Still more studies [Refs. 15, 16, 17, 18, & 19] have utilized finite difference methods to solve non-linear, three dimensional partial differential equations for rectangular enclosures.

### C. THE FIRE TEST FACILITY

A full scale test facility has been constructed at the Naval Air Warfare Center (NAWC) at China Lake, CA. This facility, designed to simulate full scale shipboard compartments, consists of three chambers [see Figure 1 on page 4 and Figure 2 on page 5]. The main chamber measures 20 feet by 20 feet by 10 feet and is vented to the atmosphere through an opening in a side wall, in a manner intended to simulate the penetration of a missile or other projectile. The second chamber measures 15 feet by 15 feet by 10 feet is located adjacent to the main chamber to the east, while the third chamber, also measuring 15 feet by 15 feet by 10 feet, is located on top of the main chamber. These secondary chambers are intended to provide a means to study the vertical and horizontal heat transmission rates. [Ref. 2, pp. 7-10]

The entire test structure is constructed of 3/8 inch thick steel bulkheads/walls reinforced by 5 inch I-beams on 5 foot centers, and 1/2 inch thick steel decks reinforced underneath by 12 inch I-beams on 5 foot centers. Additional support was provided for the overhead in the main chamber by several 5 inch I-beam columns. These columns were intended to eliminate any sagging and/or distortion of the overhead as it is repeatedly cycled from ambient conditions to the extreme temperatures expected during the missile fuel tests. Access to all three compartments is through hatches which open to the outside of the structure and are kept closed during all testing. There are no openings between any two adjacent chambers. The ventilation opening is located on the north face of the main chamber to simulate an impact hole, such as a missile strike [see Figure 3 on page 6 and Figure 4 on page 7]. [Ref. 2, pp. 10-12]

Instrumentation is provided within the test chamber to measure radiation heat flux, total heat flux, compartment bulk pressure, wall temperatures and compartment gas

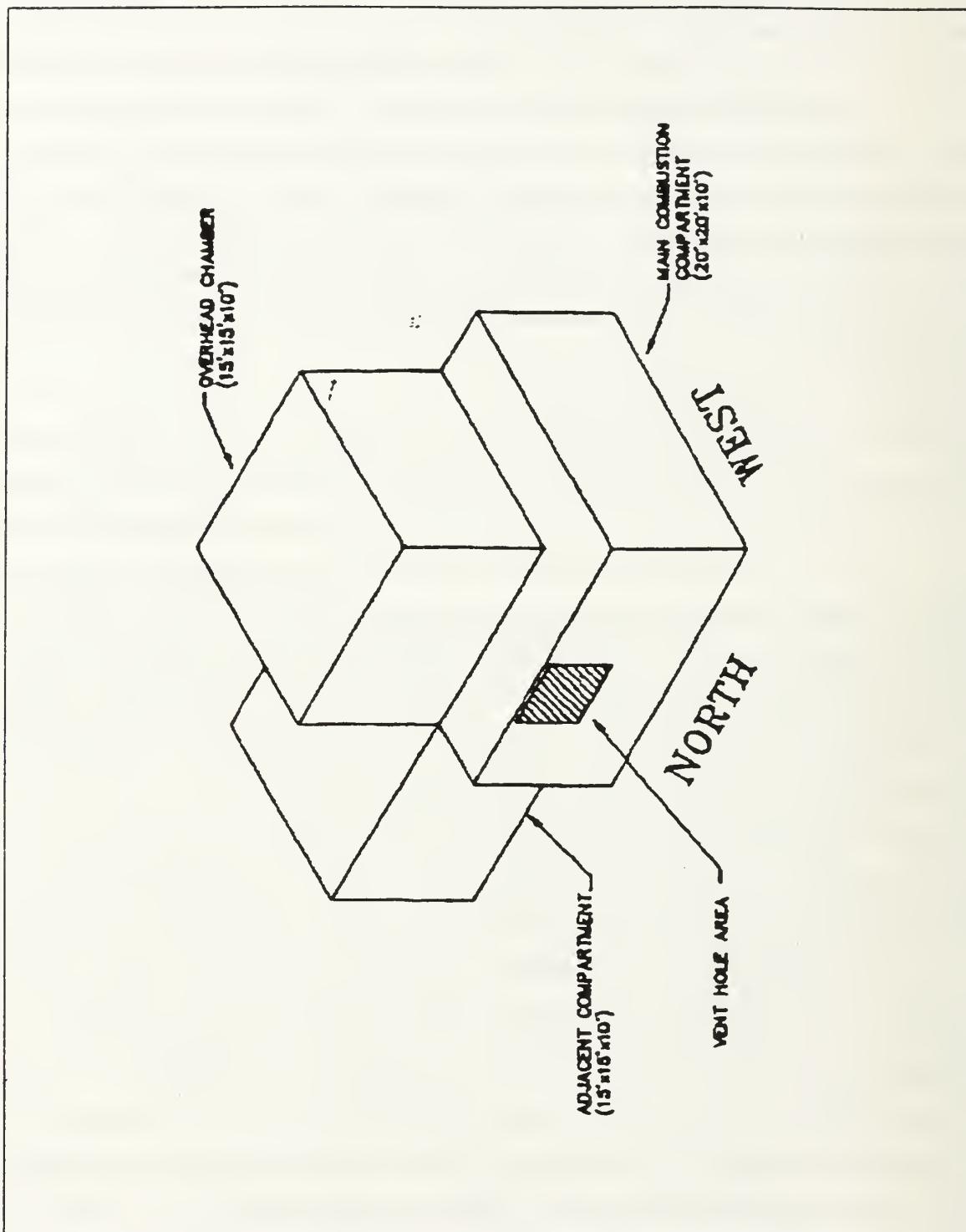


Figure 1. Fire test chamber at NAWC, China Lake, CA.

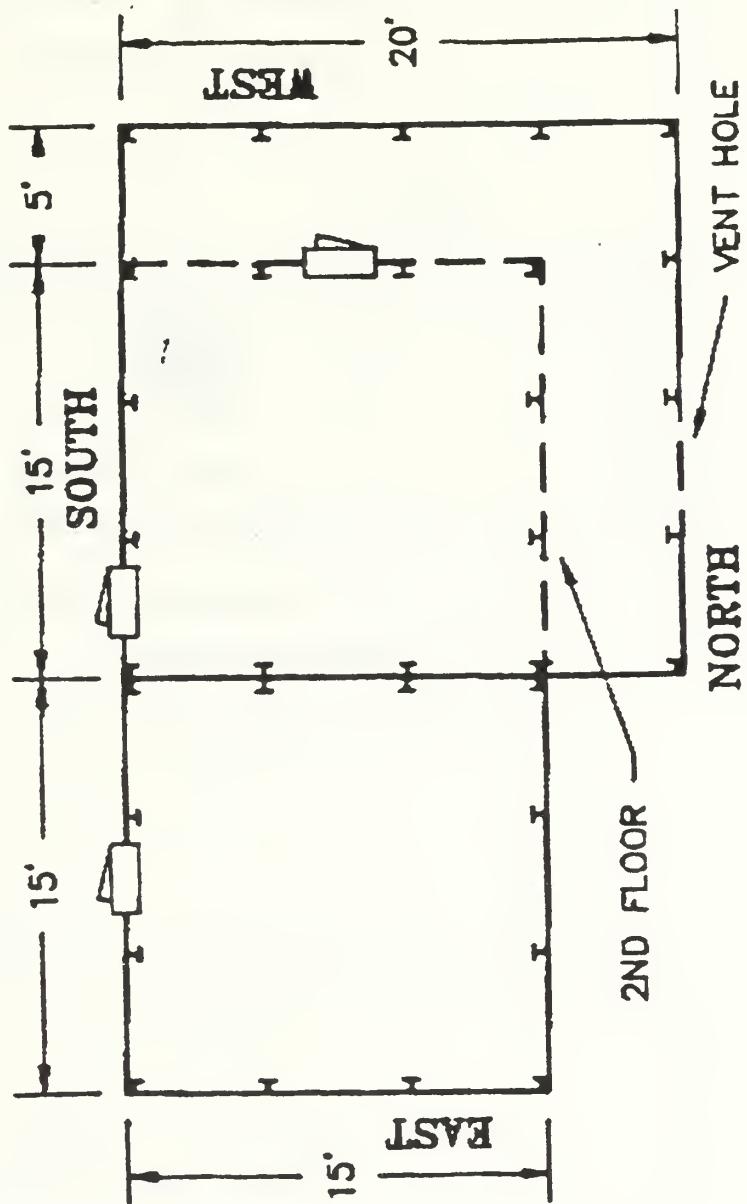


Figure 2. Plan view of fire test chamber at NAWC, China Lake, CA.

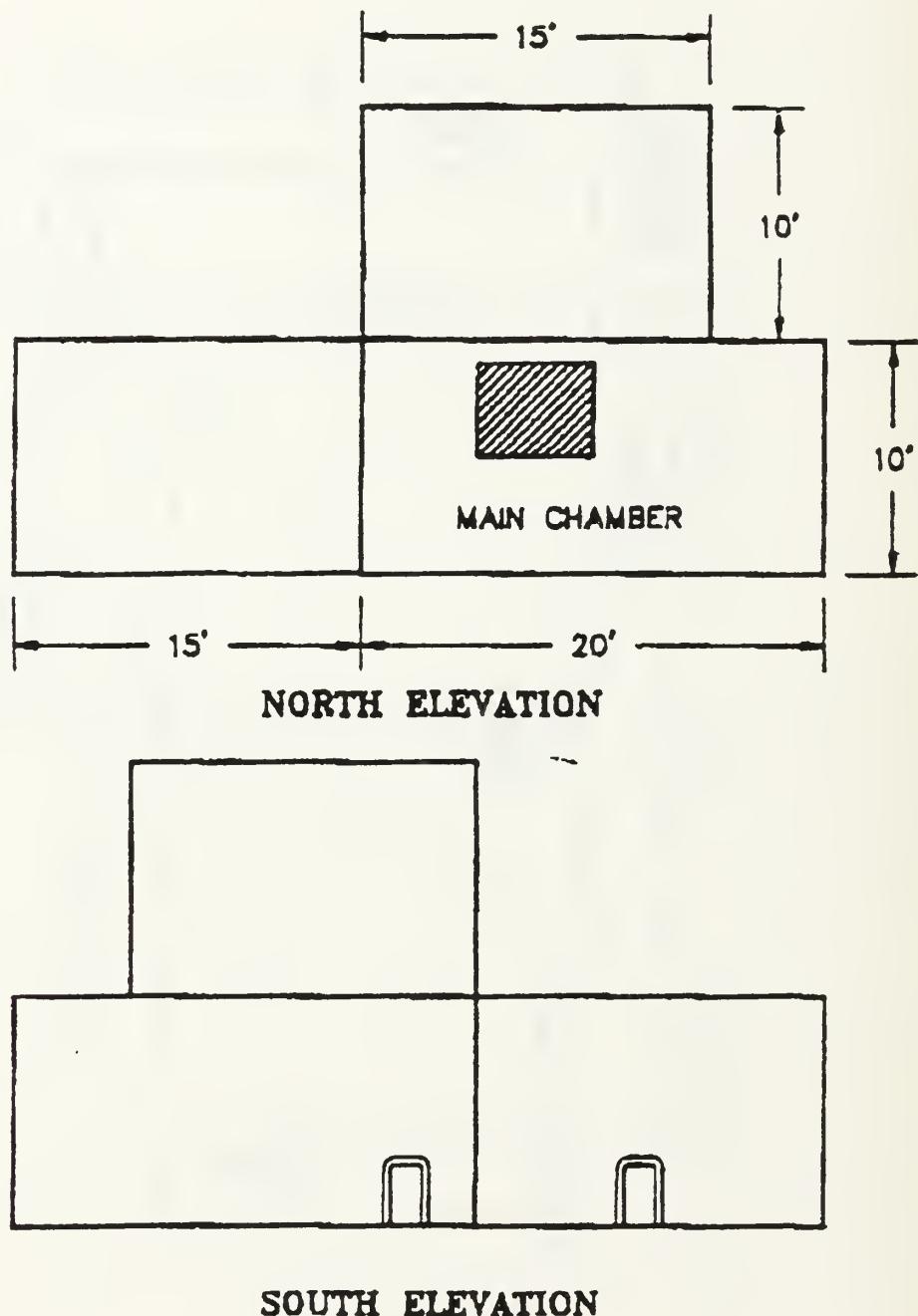
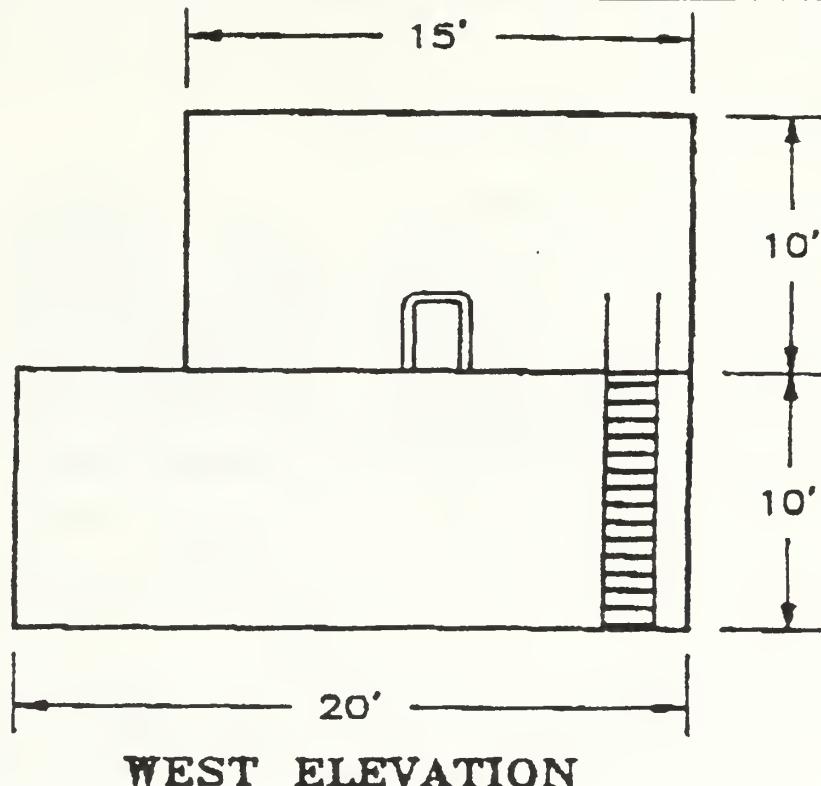
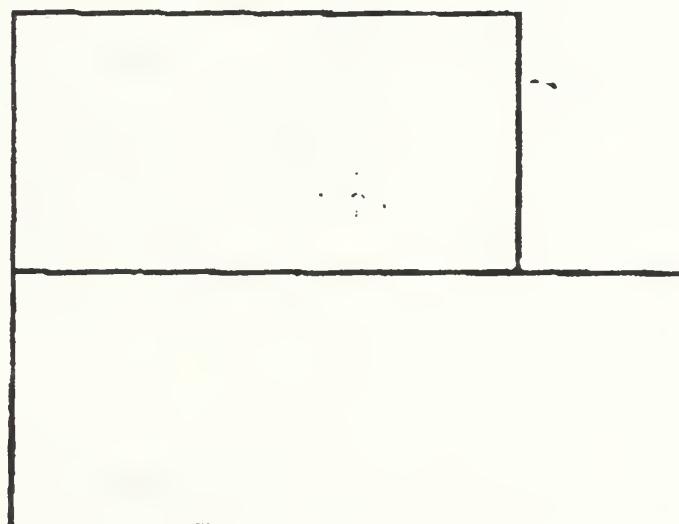


Figure 3. North/south elevations of test chamber at NAWC, China Lake, CA.



**WEST ELEVATION**



**EAST ELEVATION**

Figure 4. East/west elevations of test chamber at NAWC, China Lake, CA.

temperatures. Thermocouples were arranged in vertical arrays of 10 thermocouples. The lowest thermocouple in each array was placed 6 inches above the deck with subsequent thermocouples spaced at 1 foot intervals ending 6 inches below the ceiling [see Figure 5 on page 9]. [Ref. 2, pp. 14-15]

#### **D. THE COMPUTER PROGRAM**

This computer model is a joint project undertaken by the Naval Postgraduate School and the University of Notre Dame. It represents a low cost, safe alternative to full scale fire testing. With proper modifications, and properly validated by full scale experimentation, this program should provide a valuable tool for testing the effectiveness of fire mitigation techniques and evaluation of new ship designs.

Work on this program began at Naval Postgraduate School in 1986 when Nies [Ref. 20] used a cartesian coordinate system to model the cylindrical spherical geometry of the FIRE-1 test facility. In 1987 Raycraft [Ref. 21] modified the program to use a cylindrical spherical coordinate system. She also expanded the scope of this project by writing a companion program to calculate view factors and account for surface radiation effects. Using both of Raycraft's programs, Houck [Ref. 22] further expanded the scope of the project to account for the internal ventilation capabilities of the FIRE-1 facility. Most recently, in 1991, McCarthy [Ref. 23] used advanced computer graphics techniques to provide a more accurate pictorial representation of the unique geometry of the FIRE-1 facility and demonstrated the advantages of using full color displays to represent the three dimensional isotherm and velocity vector field profiles. This development greatly enhanced the presentation of the program output. McCarthy was also the first researcher at NPS to incorporate Raycraft's radiation/view factor program as subprograms of the main computer code.

This thesis returns to the cartesian coordinate system used by Nies [Ref. 20], to model the Navy's newest fire test facility at the Naval Air Warfare Center (NAWC) at China Lake, CA. It also advances McCarthy's [Ref. 23] work by applying the enhanced graphics capabilities of the NCAR Graphics software, developed by the National Center for Atmospheric Research [Refs. 24 and 25], for output presentation.

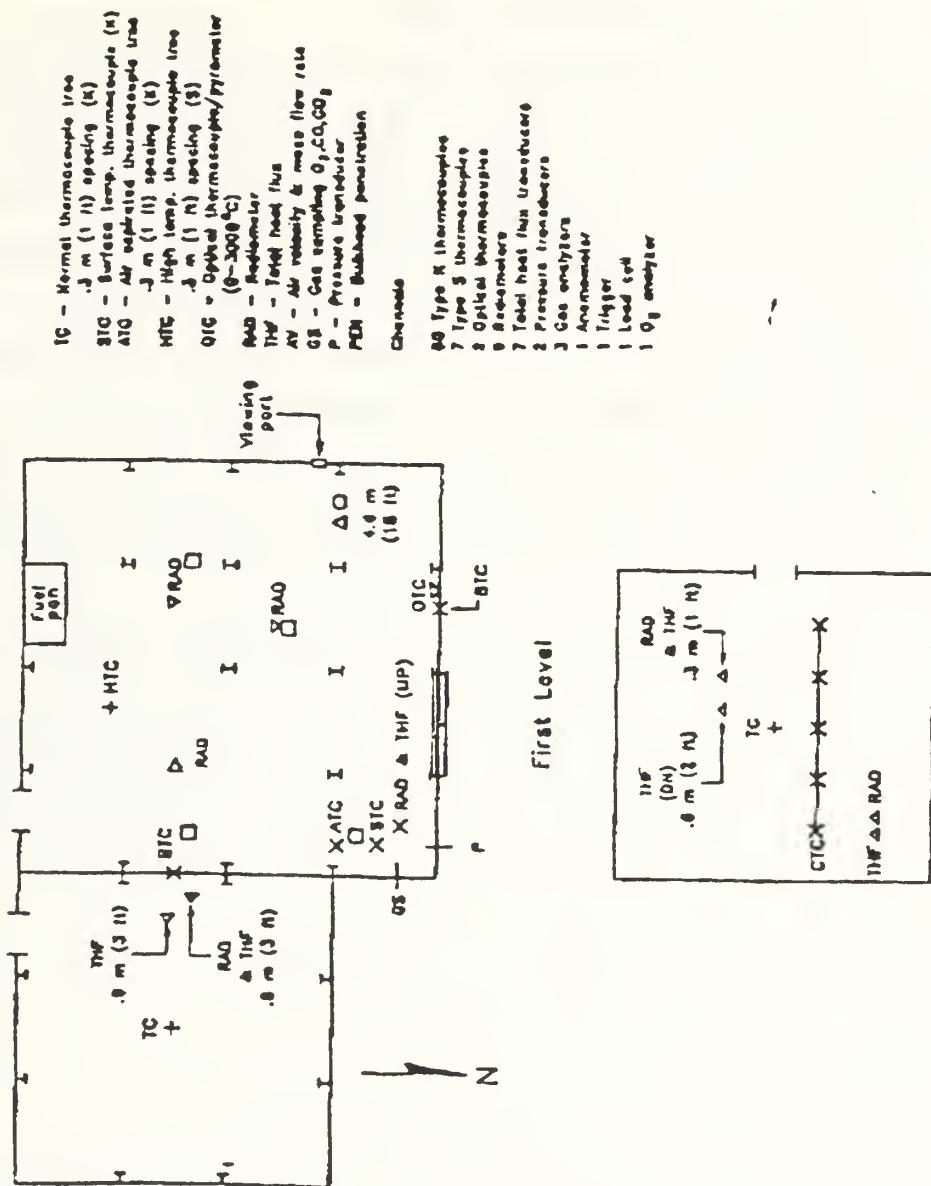


Figure 5. Instrumentation of fire test chamber at NAWC, China Lake, CA.

## II. THE NUMERICAL MODEL

### A. THE GOVERNING EQUATIONS.

The model used in this code is built on the fundamental laws of conservation of mass (continuity), energy and momentum. One example of these equations is presented by Patankar [Ref. 26, pp. 11-17]. As in that work, this model neglects the pressure work and viscous dissipation terms of the energy equation due to the low flow velocities expected. The volumetric heat generation term will be used to account for heat input by the fire. Patankar's version of the momentum equations [Ref. 26, p. 14, eq. 2.11] included both a body force and an extra viscous force. This model assumes a newtonian fluid therefore the extra viscous force is neglected and the only body force present is due to gravitational effects acting in the negative z-direction. Thus the body force in the z-momentum equation is set equal to  $-\rho g$  where  $g$  is the local gravitational constant; the negative sign indicates that  $g$  is acting in the negative z-direction; and  $\rho$  is the fluid density.

Nies [Ref. 20, pp. 16-38] expanded the equations presented by Patankar into the three dimensional, cartesian coordinate system used in this model. Following the development pattern of Doria [Ref. 18, pp. 4-7] and making the assumption that air is a homogeneous gas of constant composition (reactive variations due to the fire are neglected), Nies [Ref. 20, pp. 16-17] incorporated the equations of state for an ideal gas with constant specific heats in the form:

$$P = \rho RT$$

and

$$h = c_p(T - T_{ref})$$

where  $P$ ,  $T$  and  $\rho$  represent the bulk pressure, temperature and density inside the control volume,  $R$  is the gas constant for air,  $h$  is the specific enthalpy,  $c_p$  is the specific heat and  $T_{ref}$  is a suitably chosen reference temperature.

Again, following the procedures developed by Patankar [Ref. 26] and expanded by Doria [Ref. 18], Nies [Ref. 20, pp. 21-26] goes on to place these six equations in their non-dimensional, integral forms. After subdividing the test chamber into a large, but

finite number of control volumes, finite difference techniques are used to solve for the six unknowns of temperature, pressure, density and the three components of velocity.

## B. THE CONTROL VOLUME.

Each control volume, or cell, is defined by the nodal point contained at its center. Values for temperature, density and pressure are calculated at this central point (designated  $P$ ) and are then assumed to hold for the entire cell. A secondary, or staggered grid system, is used to determine velocities. This staggered grid is offset from the main grid by one half the length of the cell [see Figure 6 on page 12]. As explained in McCarthy [Ref. 23, pp. 18-19] and Patankar [Ref. 26, pp. 115-120], use of this staggered grid alleviates two problems: first, since velocities are dependent upon pressure differentials, the staggered grid allows pressures to be determined at a more frequent interval thereby reducing the error associated with larger separations between nodal points; second, the stagger increases stability by decreasing and/or eliminating unrealistic, oscillatory velocity fields when adjacent velocities are used to satisfy the continuity equation.

Since Patankar's method uses primitive variables, in lieu of the stream function and vorticity, special attention must be paid to the coupling of equations through the pressure terms. An iterative process is used to calculate the pressure in each cell, then a local pressure correction is calculated to ensure that continuity is satisfied. Additional discussions of this correction are included in both Patankar [Ref. 26, pp.120-128] and Doria [Ref. 18, pp. 26-32]. A global pressure correction was described by Nicolette, *et al* [Ref. 14] for addressing net energy changes within the closed compartment. This correction has also been incorporated into this model.

As stated in McCarthy [Ref. 23, p. 19], forcing convergence on a non-linear set of equations, like those describing fluid flow, can be difficult. A variety of schemes have been developed, each with its own set of strengths and weaknesses. This model applies iterative techniques to a solution scheme known as "QUICK", or Quadratic Upstream Interpolation for Convective Kinematics, developed by Leonard [Ref. 19]. With the accuracy of a central differencing scheme and the stability of the convective diffusion terms in upwind differencing, the QUICK scheme estimates values and gradients of the transport variables at the cell faces. The utility of this method was demonstrated by H.Q. Yang [Ref. 27] when he used QUICK to solve the coupled momentum and energy equations for three dimensional flow in a tilted rectangular enclosure.

In addition to the center cell described above, neighboring cells will be used in various computations. To keep track of these cells a standardized nomenclature must be

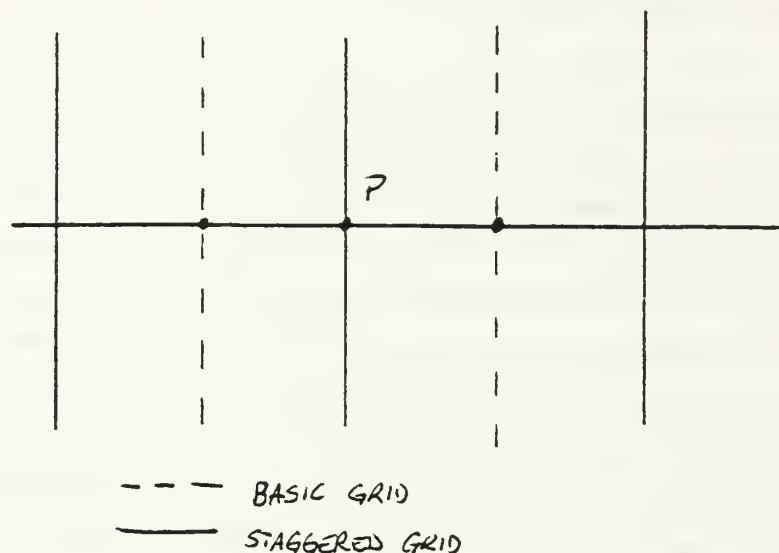


Figure 6. One Dimensional Basic and Staggered Computational Cells.

adopted. Assuming the central cell, cell P, to be located at the point (i,j,k) where i,j and k correspond to the standard coordinate axis x, y and z respectively, then each neighbor may be described as follows (NOTE: the following directions are for standardization of nomenclature only and do not necessarily correspond to compass directions as shown in Figure 1 on page 4):

East (i + 1,j,k)

West (i-1,j,k)

North (i,j + 1,k)

South (i,j-1,k)

Front (i,j,k + 1)

Back (i,j,k-1)

The nodal point in each direction is designated by the capital letter corresponding to the direction (i.e. E, W, N, S, F, B), while the boundary between cell P and its neighbors is designated by a lower case letter corresponding to that direction (i.e. the boundary between cell P and cell N is designated n, and the boundary between P and F is f). A typical cell array on a rectangular grid is shown in figure Figure 7 on page 13.

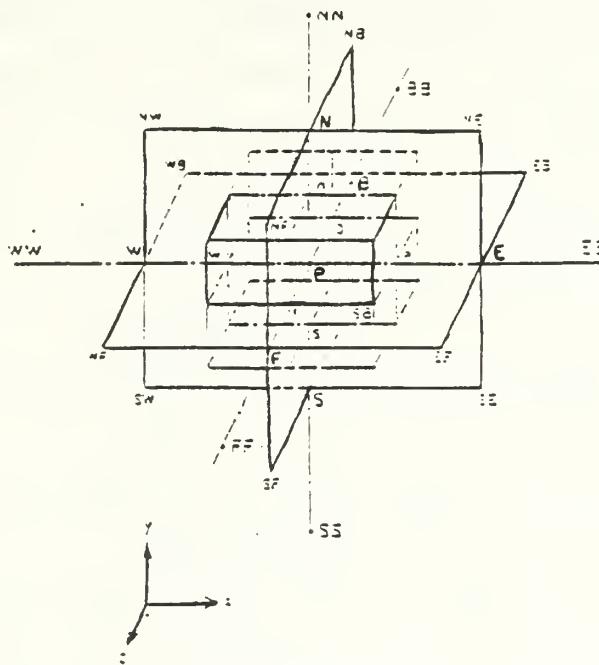


Figure 7. Basic Cell Nomenclature on a Rectangular Grid.

As discussed previously, each P node is used to determine values of density, pressure and temperature which are then applied to its entire cell. Velocities are determined at the cell faces using the staggered grid arrangement described above.

### C. DISCRETIZATION OF THE CONSERVATION EQUATIONS.

With that brief background, the integral forms of the conservation equations developed by Nies [Ref. 20, pp. 25-26] may now be discretized. As discussed by Nies [Ref. 20, pp. 26-38] maximum stability and accuracy of the model is achieved by using three different finite differencing schemes. Forward differencing is used for timewise discretization, central differencing is used to discretize the diffusion terms, and the QUICK scheme is used to discretize the convective terms. Use of these techniques to discretize the governing equations was discussed in detail by Nies [Ref. 20, pp. 26-38] and will not be repeated here. The following finite difference forms of the governing equations are taken from his work.

#### 1. The Continuity Equation.

$$(\rho_p - \rho_p^0) \frac{\Delta x \Delta y \Delta z}{\Delta t} + (G_e - G_w) \Delta y \Delta z + (G_n - G_s) \Delta z \Delta x + (G_f - G_b) \Delta x \Delta y = S_{mp}$$

where  $\rho_p$  is the density at the current time step;  $\rho_p^0$  is the density at node P at the previous time step;  $\Delta t$  is the incremental time step;  $\Delta x$ ,  $\Delta y$ , and  $\Delta z$  are the cell dimensions in the indicated direction; and  $S_m^p$  is the residual mass term. The mass flux (G) terms are defined as:

$$G_e = \frac{(\rho_E + \rho_P)}{2} u_e$$

$$G_w = \frac{(\rho_P + \rho_W)}{2} u_w$$

$$G_n = \frac{(\rho_N + \rho_P)}{2} v_n$$

$$G_s = \frac{(\rho_P + \rho_S)}{2} v_s$$

$$G_f = \frac{(\rho_F + \rho_P)}{2} w_f$$

$$G_b = \frac{(\rho_P + \rho_B)}{2} w_b$$

It should be noted that in all of these equations  $\rho$  refers to the density;  $u$ ,  $v$ , and  $w$  are the three velocity components in the x, y, and z-directions respectively; uppercase subscripts denote values at the indicated nodal point; and lowercase subscripts denote values at cell faces. Also, in order for continuity to be satisfied in this closed system, the residual mass term ( $S_m^p$ ) would equal zero. However, due to the approximation inherent in the numerical scheme, we will be satisfied if  $S_m^p$  tends toward zero as determined by comparison to an arbitrarily small threshold value.

## 2. The Energy Equation.

$$\left[ H_{A_P} + \rho_P^0 \frac{\Delta x \Delta y \Delta z}{\Delta t} \right] h_P = H_{A_E} h_E + H_{A_W} h_W + H_{A_N} h_N + H_{A_S} h_S + H_{A_F} h_F + H_{A_B} h_B + H_{S_P}$$

where  $h$  is the specific enthalpy at the current time step;  $h^0$  is the specific enthalpy at the previous time step; and the coefficients (H) are defined as:

$$H_{A_E} = \frac{(|G_e| - G_e)}{2} \Delta y \Delta z + \left( \frac{1}{Re_t Pr_t} \right)_e \frac{\Delta y \Delta z}{\Delta x}$$

$$H_{A_w} = \frac{(|G_w| + G_w)}{2} \Delta y \Delta z + \left( \frac{1}{Re_t Pr_t} \right)_w \frac{\Delta y \Delta z}{\Delta x}$$

$$H_{A_n} = \frac{(|G_n| - G_n)}{2} \Delta z \Delta x + \left( \frac{1}{Re_t Pr_t} \right)_n \frac{\Delta z \Delta x}{\Delta y}$$

$$H_{A_s} = \frac{(|G_s| + G_s)}{2} \Delta z \Delta x + \left( \frac{1}{Re_t Pr_t} \right)_s \frac{\Delta z \Delta x}{\Delta y}$$

$$H_{A_f} = \frac{(|G_f| - G_f)}{2} \Delta x \Delta y + \left( \frac{1}{Re_t Pr_t} \right)_f \frac{\Delta x \Delta y}{\Delta z}$$

$$H_{A_b} = \frac{(|G_b| + G_b)}{2} \Delta x \Delta y + \left( \frac{1}{Re_t Pr_t} \right)_b \frac{\Delta x \Delta y}{\Delta z}$$

$$H_{A_p} = H_{A_E} + H_{A_w} + H_{A_n} + H_{A_s} + H_{A_f} + H_{A_b}$$

$$H_{S_p} = \rho_p^0 h_p^0 \Delta x \Delta y \Delta z$$

Also used above are the turbulent Reynolds number ( $Re_t$ ) and the turbulent Prandtl number ( $Pr_t$ ). These are defined as

$$Re_t = \frac{\rho_0 u_0 H}{\mu_{eff}}$$

$$Pr_t = \frac{\mu_{eff} c_{p0}}{k_{eff}}$$

where  $H$  is the characteristic length (defined as the height of the test chamber in our model);  $\rho$  and  $c_p$  represent the density and specific heat of air, while the subscript 0 indicates that the properties are to be evaluated at the initial conditions which existed prior to ignition of the fire;  $u_0$  is the reference velocity (set equal to 1.0 ft/sec); and  $\mu_{eff}$  and  $k_{eff}$  are effective values of viscosity and conductivity as defined by Nies [Ref. 20, p. 39-40].

### 3. The Momentum Equations.

As stated by Nies [Ref. 20, p. 31] the momentum equations are more complex than the previous equations because of the use of the staggered grid and the addition of the shear stress terms. Staggered grids are determined by shifting the main grid one half cell in the negative direction along one axis at a time. Maintaining the nomencla-

ture established for the basic, centered cells, the central node of a cell staggered in the x-direction becomes w, the central node in a cell staggered in the y-direction becomes s, and the central node in a cell staggered in the z-direction becomes b. Likewise, the faces of the staggered cell are designated by the capital letters representing the basic nodes through which they pass. Thus, in the staggered grid P always represents the positive face along the axis where the shift (stagger) is being evaluated. Thus, the x-momentum equation becomes:

$$\left[ A_w + \rho_w^0 \frac{\Delta x \Delta y \Delta z}{\Delta t} \right] u_w = A_e u_e + A_{ww} u_{ww} + A_{Nw} u_{Nw} + A_{Sw} u_{Sw} + A_{Fw} u_{Fw} + A_{Bw} u_{Bw} + S_w$$

where

$$\begin{aligned} A_e &= \left[ \frac{(|G_P| - G_P)}{2} + \frac{(\frac{1}{Re_t})_P}{\Delta x} \right] \Delta y \Delta z \\ A_{ww} &= \left[ \frac{(|G_{ww}| + G_{ww})}{2} + \frac{(\frac{1}{Re_t})_{ww}}{\Delta x} \right] \Delta y \Delta z \\ A_{Nw} &= \left[ \frac{(|G_{nw}| - G_{nw})}{2} + \frac{(\frac{1}{Re_t})_{nw}}{\Delta y} \right] \Delta z \Delta x \\ A_{Sw} &= \left[ \frac{(|G_{sw}| + G_{sw})}{2} + \frac{(\frac{1}{Re_t})_{sw}}{\Delta y} \right] \Delta z \Delta x \\ A_{Fw} &= \left[ \frac{(|G_{fw}| - G_{fw})}{2} + \frac{(\frac{1}{Re_t})_{fw}}{\Delta z} \right] \Delta x \Delta y \\ A_{Bw} &= \left[ \frac{(|G_{bw}| + G_{bw})}{2} + \frac{(\frac{1}{Re_t})_{bw}}{\Delta z} \right] \Delta x \Delta y \\ A_w &= A_e + A_{ww} + A_{Nw} + A_{Sw} + A_{Fw} + A_{Bw} \end{aligned}$$

$$\begin{aligned}
S_w &= \rho_w^0 u_w^0 \frac{\Delta x \Delta y \Delta z}{\Delta t} - (P_p - P_w) \Delta y \Delta z \\
&+ (u_p - u_{ww}) \left( \frac{1}{Re_t} \right)_p \frac{\Delta y \Delta z}{\Delta x} - (u_w - u_{ww}) \left( \frac{1}{Re_t} \right)_{ww} \frac{\Delta y \Delta z}{\Delta x} \\
&+ \left[ (v_{Nw} - v_{Nww}) \left( \frac{1}{Re_t} \right)_{nw} - (v_w - v_{ww}) \left( \frac{1}{Re_t} \right)_{sw} \right] \Delta z \\
&+ \left[ (w_{wf} - w_{wwf}) \left( \frac{1}{Re_t} \right)_{wf} - (w_w - w_{ww}) \left( \frac{1}{Re_t} \right)_{bw} \right] \Delta y
\end{aligned}$$

and

$$\rho_w^0 = \frac{\rho_p^0 + \rho_w^0}{2}$$

$$u_p = \frac{u_e + u_w}{2}$$

$$u_w = \frac{u_w + u_{ww}}{2}$$

$$u_{nw} = \frac{u_{Nw} + u_w}{2}$$

$$u_{sw} = \frac{u_{Sw} + u_w}{2}$$

$$u_{fw} = \frac{u_{Fw} + u_w}{2}$$

$$u_{bw} = \frac{u_{Bw} + u_w}{2}$$

$$G_p = \rho_p u_p$$

$$G_w = \rho_w u_w$$

$$G_{nw} = \frac{\left[ \frac{\rho_N + \rho_p}{2} v_n + \frac{\rho_{Nw} + \rho_w}{2} v_{nw} \right]}{2}$$

$$G_{sw} = \frac{\left[ \frac{\rho^P + \rho_S}{2} v_s + \frac{\rho_W + \rho_{SW}}{2} v_{sw} \right]}{2}$$

$$G_{fw} = \frac{\left[ \frac{\rho_F + \rho_P}{2} w_f + \frac{\rho_{FW} + \rho_W}{2} w_{fw} \right]}{2}$$

$$G_{bw} = \frac{\left[ \frac{\rho_P + \rho_B}{2} w_b + \frac{\rho_W + \rho_{BW}}{2} w_{bw} \right]}{2}$$

Development of the equations for y and z-momentum proceed in a similar fashion and will not be repeated here in the interest of brevity.

## D. PRESSURE CORRECTIONS.

### 1. Global Pressure Corrections.

As described by Nies [Ref. 20, pp. 50-52] and McCarthy [Ref. 23, pp.47-48], in a fixed mass - fixed volume system, overall pressure depends on the net energy added or removed from the system. Nicolette, *et al*, [Ref. 14] demonstrated that in such a system, with a uniform grid, the sum of the product of density times volume for all of the cells remains fixed at the total mass of the system. Therefore, at any time during the fire, the total mass of the system must equal the initial mass at the equilibrium density which existed before the fire was ignited. This may be expressed as:

$$\sum_i \rho_i^n (\Delta x \Delta y \Delta z)_i = \sum_i \rho_{EQ,i} (\Delta x \Delta y \Delta z)_i$$

Since the grid is uniform, the term  $(\Delta x \Delta y \Delta z)_i$  is a constant, independent of time, it may be divided out of both sides of the equation leaving:

$$\sum_i \rho_i^n = \sum_i \rho_{EQ,i}$$

Now, since we are operating under the assumption that the fluid inside our burn chamber is an ideal gas, and recalling that we are also working in a fixed volume environment, the density ( $\rho$ ) may now be expressed as a function of pressure and temperature only.

$$\rho_i = f(P, T)_i$$

The actual pressures and temperatures may now be expressed as the sum of an estimated value ( $P^*$  and  $T^*$ ) and a global correction ( $P_g$  and  $T_g$ ).

$$P = P^* + P_g$$

$$T = T^* + T_g$$

Now applying the ideal gas law and substituting into the summation relation shown above, we can solve for the global pressure correction as

$$P_g = \frac{\sum_i P_{EQ} \left( \frac{1}{T_i} - \frac{1}{T^*} \right) - \sum_i \frac{P^*}{T^*}}{\sum_i \frac{1}{T^*}}$$

This relation is then iterated until a global pressure correction is obtained which conserves mass for all the cells.

## 2. Local Pressure Corrections.

As explained by both McCarthy [Ref. 23, pp.49-51] and Nies [Ref. 20, pp. 52-54], the method for obtaining the local pressure correction was developed by Patankar [Ref. 26, pp. 120-126] and Doria [Ref. 18, pp. 26-32] and is similar to the method used for determination of the global pressure correction. For this correction, the pressure distribution found during the previous time step is used to estimate the velocity field. Continuity is then applied and residual mass terms ( $S_{m\rho}$ ) are calculated for each cell. Based on these residual mass terms a pressure correction is estimated and the process is repeated until the values of  $S_{m\rho}$  fall below a previously established threshold value at which point the final value of the correction is now known. As in the determination of the global pressure correction, the total pressure is expressed as the sum of the estimated pressure and the local correction.

$$P = P^* + P'$$

where  $P$  is the total pressure,  $P^*$  is the estimated pressure, and  $P'$  is the local pressure correction. The local pressure correction may now be expressed in its finite difference form

$$A_P P' = A_E P'_E + A_W P'_W + A_N P'_N + A_S P'_S + A_F P'_F + A_B P'_B - S_{mp} \Delta x \Delta y \Delta z$$

where

$$A_E = \frac{\rho_e (\Delta y \Delta z)^2}{A_e + \rho_e \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

$$A_W = \frac{\rho_w (\Delta y \Delta z)^2}{A_w + \rho_w \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

$$A_N = \frac{\rho_n (\Delta z \Delta x)^2}{A_n + \rho_n \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

$$A_S = \frac{\rho_s (\Delta z \Delta x)^2}{A_s + \rho_s \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

$$A_F = \frac{\rho_f (\Delta x \Delta y)^2}{A_f + \rho_f \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

$$A_B = \frac{\rho_b (\Delta x \Delta y)^2}{A_b + \rho_b \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

$$A_P = A_E + A_W + A_N + A_S + A_F + A_B$$

At solid boundaries where the mass flux ( $G$ ) is zero, the appropriate coefficient ( $A$ ) corresponding to that boundary is also set equal to zero.

After the local pressure correction ( $P'$ ) is determined, new velocities are determined from the following relations:

$$u = u^x + u'$$

$$v = v^x + v'$$

$$w = w^x + w'$$

where

$$u' = \frac{(P'_P - P'_W)\Delta y \Delta z}{A_w + \rho_w \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

$$v' = \frac{(P'_P - P'_S)\Delta z \Delta x}{A_s + \rho_s \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

$$w' = \frac{(P'_P - P'_B)\Delta x \Delta y}{A_b + \rho_b \frac{\Delta x \Delta y \Delta z}{\Delta t}}$$

The residual mass ( $S_{mp}$ ) is again compared to the threshold value and the entire process is iterated if necessary.

## E. INITIAL AND BOUNDARY CONDITIONS.

Before this system of equations can be solved, appropriate initial and boundary conditions must be determined and applied. As in the previous work conducted by Nies, Raycraft, Houck and McCarthy [Refs. 20, 21, 22, and 23], these conditions are established as follows:

### 1. Initial Conditions.

The initial conditions for the model are determined by the conditions existing inside the test chamber just prior to starting the fire. It is assumed that the air is uniformly at rest, thus all components of velocity are set equal to zero throughout the chamber. The temperature inside the chamber is assumed to be uniform and equal to the ambient temperature outside the chamber, therefore the non-dimensional temperature field is set equal to 1.0 throughout the model. Finally, pressure and density are also assumed to be uniformly distributed and in static equilibrium.

### 2. Boundary Conditions.

The chamber walls are constructed of standard 3/8 inch sheet steel [Ref. 2, p. 10], therefore they are presumed to be non-porous. This allows all velocity components

to be set equal to zero at the wall (the so called "no slip" condition), and the mass flux across the wall is also set to zero (the "impermeable wall" condition). Since there is no heat generation inside the walls of the chamber, it can be assumed that no discontinuities exist between the temperature of the surface of the wall and the air immediately adjacent to it. Therefore the inside surface temperature of the wall must be identically equal to the temperature of the fluid immediately adjacent to it. These condition may be expressed as follows:

$$u_{surf} = 0$$

$$v_{surf} = 0$$

$$w_{surf} = 0$$

$$T_{surf} = T_{air}$$

Finally, conservation of energy must also be satisfied at the wall. Therefore

$$q_r - k_{air} \frac{\delta T_{air}}{\delta n} = - k_{surf} \frac{\delta T_{surf}}{\delta n}$$

where  $n$  represents the inward pointing normal at that location; and  $q_r$  represents the energy transfer due to thermal radiation.

## F. MODELING OF PHYSICAL PHENOMENA.

### 1. Wall Conduction.

Heat losses through the walls are calculated assuming one dimensional, unsteady heat conduction through walls of uniform conductivity. A constant convective heat transfer condition is assumed to exist between the exterior of the wall and the environment.

### 2. Turbulence.

As explained by McCarthy [Ref. 23, pp. 15-16] and Nies [Ref. 20, pp. 39-40] the turbulence model used in this code is a simple algebraic model first developed by Nee and Liu [Ref. 28]. This model calculates an effective viscosity ( $\mu_{eff}$ ) and an effective conductivity ( $k_{eff}$ ) for recirculating buoyant flows with widely fluctuating turbulence levels. Development of these equations, as used in this model, is shown in Nies [Ref. 20, p. 39-40].

### 3. Radiation.

The radiation model used in this code considers only surface radiation while considering the gas and smoke to be transparent. Developed and explained in detail by Raycraft [Ref. 21], the model is based on the net radiosity method discussed by Sparrow and Cess [Ref. 29]. As summarized by McCarthy [Ref. 23, p. 17], the model treats both the chamber walls and the flame areas as grey, diffuse surfaces.

### III. THE COMPUTER PROGRAMS

#### A. INTRODUCTION.

Running the computer code for this project, from initial data input to final graphical output, is a three step process. Initial input is accomplished using the program FIREBLD; numerical data output is generated by the program FIRE; and final graphical output is provided by the programs ISOTHERM and VELOCITY, both of which are written to utilize the graphics software developed by the National Center for Atmospheric Research (NCAR).

#### B. PROGRAM FIREBLD.

Program FIREBLD [Appendix A] is used to build and or modify the data file FIRE.DATA which provides the input data required to run the main code, FIRE. Originally part of SUBROUTINE INPUT in FIRE, FIREBLD represents an effort to improve the "user friendliness" of the code. It accomplishes this by creating an interactive input environment which attempts to minimize the user's need for detailed knowledge of the internal operation of FIRE. As the user friendliness of the SUBROUTINE INPUT increased, so did its length. It quickly became the largest subroutine in FIRE, and in an effort to streamline that code, it was converted into a separate program. This conversion had two advantageous effects:

1. It increased the run time options for FIRE by eliminating the need for direct operator input while running the program. This allows FIRE to take advantage of the time savings associated with running in background and or batch modes; and
2. Elimination of the necessity for direct operator input has reduced the total run time of the code (FIRE) by placing the slow process of data input in a separate program.

FIREBLD is designed to query the user regarding the various input parameters, indicating the proper units when appropriate. It begins by looking for a previously created input file. If one is found the user is asked if it should be used, a negative response causes program termination, while a positive response causes the data file to be read. The program then continues by displaying the existing data and asking the user if any changes are desired. If a previously created input file is not located, FIREBLD automatically enters input mode and prompts the user for the required information.

Some of the input data used in this project is shown in Table 1 on page 25 and Table 2 on page 26. Additional data which may be input at the user's discretion includes:

Thermocouple data, including number and location. The present code is limited to a maximum of 20 thermocouples, but this may be changed with only minor modifications to the code.

Mass source data, including location and size. This portion of the code was not required for this project and therefore has not been tested.

Internal solids data, including location, size, conductivity, specific heat, and fan speed. The fan speed included here is for internal ventilation contained wholly inside the test chamber. This is similar to the ventilation incorporated into the code by Houck [Ref. 22]. The problems experienced by McCarthy [Ref. 23] in association with this ventilation, have not been seen here. It should also be noted that the external chamber walls are input as internal solids.

**Table 1. INPUT DATA**

	Directions		
	X	Y	Z
<b>Chamber dimensions</b>			
Length (feet)	20.0	20.0	10.0
Wall thickness (inches)		0.375	
Floor/ceiling thickness (inches)		0.5	
<b>Number of Computational Cells</b>			
Inside the chamber	20	20	10
Total number of cells	24	24	14
<b>Fire location</b>			
Starting node	19	4	0
Ending node	20	8	1
<b>Times (seconds)</b>			
Total length of run		90.0	
Incremental time step		0.003125	
Between data saves		30.0	
Between data saves for plotting		30.0	
Fire start time		0.0	

**Table 2. WALL DATA:** The following data is input through FIREBLD to identify the location of the chamber walls.

	Location		
	X	Y	Z
Wall #1, starting node	0	0	0
Wall #1, number of nodes	1	21	11
Wall #2, starting node	0	0	0
Wall #2, number of nodes	21	1	11
Wall #3 (floor), starting node	0	0	0
Wall #3, number of nodes	21	21	1
Wall #4 (ceiling), starting node	0	0	11
Wall #4, number of nodes	21	21	11
Wall #5, starting node	0	21	0
Wall #5, number of nodes	21	1	11
Wall #6, starting node	21	0	0
Wall #6, number of nodes	1	21	11

### C. PROGRAM FIRE.

Operational details of the main program FIRE [Appendix B] are provided by McCarthy [Ref. 23, pp. 55-56]. The only significant difference between his version of the program and the present version (neglecting the obvious difference of compartment geometry) is that the separate program required by McCarthy for the generation of view factors, is incorporated into the present code as a subroutine, SUBROUTINE VIEW. Also, the present code inputs the wall locations and properties as "internal solids", as noted above.

Heat input from the fire is modeled as a volumetric heat source based on the dimensions of the fire as provided by FIREBLD. The magnitude of this heat source is calculated in SUBROUTINE CALQ. It is based on the known heat of combustion of the fuel used (2600 Btu/lbm, as provided by NAWC, China Lake, CA) and an estimated burn rate of 1.0 lbm/sec. However, due to temperature and velocity instabilities associated with this high heat generation rate, it was necessary to reduce the burn rate by two

orders of magnitude to 0.01 lbm/sec in order to achieve stable output data. Increasing the burn rate to its proper level would necessitate reductions in the time step used, and require multiple data runs to confirm stable output. Due to time restrictions placed on completion of this work, those additional data runs were left for later investigators.

In making comparisons to McCarthy's work [Ref. 23, p. 55], it is interesting to note that he used the VAXSTATION 3100 which required approximately 3600 seconds of CPU time to process one second of fire time. The current work required approximately 677 seconds of CPU time per second of fire time, utilizing the AMDAHL #### mainframe processor here at Naval Postgraduate School. Even when performance is broken down further, to a CPU seconds per fire second per cell basis, the AMDAHL out performs the VAX by a 5.5 or 6 to 1 margin. Although no attempt was made to determine the source of this improvement, the majority of it can be attributed to the increased clock speed of the AMDAHL machine, which unconfirmed estimates place at approximately 4 to 1 over the VAX.

#### D. GRAPHICAL ANALYSIS.

The value of graphical analysis was successfully demonstrated by McCarthy [Ref. 23]. This work utilizes a different graphics software package in order to standardize the software used at both Naval Postgraduate School and the University of Notre Dame. The software package chosen, NCAR Graphics, was created at the National Center for Atmospheric Research (NCAR) and is intended specifically for scientific applications. The primary advantage of NCAR over the previously used graphics software is in the flexibility of output presentation built in to the NCAR software.

The two graphics program used in the present study, ISOTHERM [Appendix C] and VELOCITY [Appendix D] each utilize the three dimensional PLOT.DATA file created by FIRE to generate two dimensional temperature and velocity profiles as requested by the user. Each program allows the user to specify the desired two dimensional view (or section) (i.e. Plan view, X-Z profile, or Y-Z profile) and the location (or elevation) in the third dimension where that section is to be taken. Each program then performs two linear interpolations, the first to locate the requested section, and the second to convert the grid used by FIRE to a uniform grid as required by the NCAR Graphics software.

Scaling of the output in each program is accomplished in different manners. VELOCITY sets the maximum vector size in any given plot by the maximum interpolated velocity for that section (NOTE: velocities are shown in centimeters per second). While the color scale used in each plot generated by ISOTHERM is determined by dividing the

range from ambient ( $70^{\circ}\text{ F} = 21.1^{\circ}\text{ C}$ ) to the maximum temperature in the non-interpolated data into 14 color zones. These scaling techniques are examples of the flexibility of the NCAR Graphics software, and each user may customize the output to satisfy the current needs/desires with minimal effort.

Color isotherm graphics are printed on a DEC LJ250 Companion Color printer using ink jet technology, attached to a VAXStation 3100 M38 standalone workstation. Velocity profiles are printed on a DEC LN03 Laser printer attached to the VAX cluster in the Mechanical Engineering Department at the Naval Postgraduate School. The following figures [Figure 8 on page 29 through Figure 25 on page 46] show the temperature and velocity profiles for each of the available view planes at 30, 60 and 90 seconds of fire time. Elevations are shown on each figure and were chosen to provide a plan view at mid-compartment height and profiles through the fire. Also included in both ISOTHERM and VELOCITY is the option to "zoom" in on any localized region of the plot as desired by the user. Figure 26 on page 47 and Figure 27 on page 48 demonstrate this capability. Note also, that the axis on all of these plots are marked (in feet) to indicate the section being viewed.

PLAN VIEW (Z = 5.0 FT.) AT 30.0 SEC.

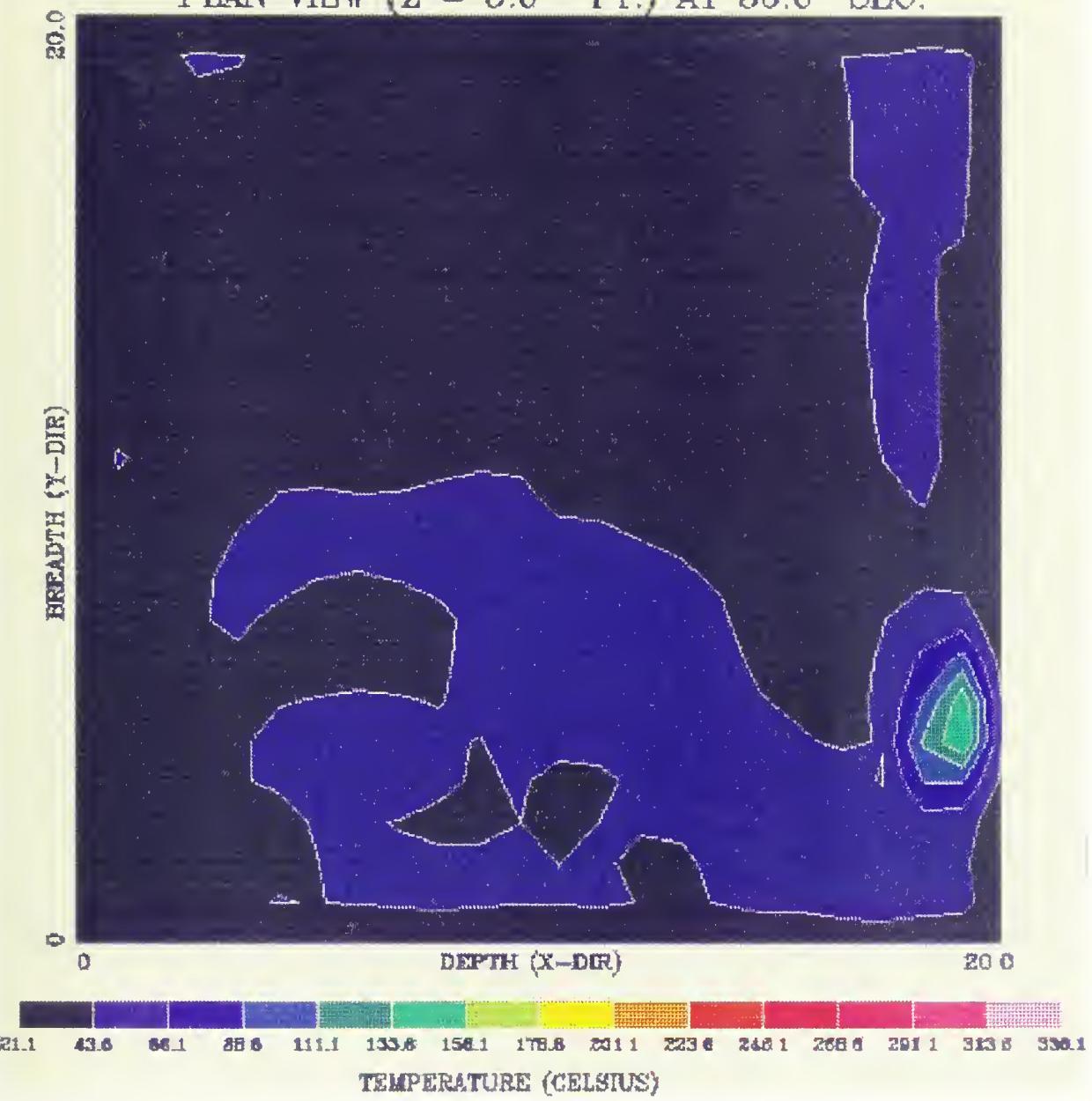


Figure 8. Temperature Profile, Plan View, 30 seconds.



PLAN VIEW (Z = 5.0 FT.) AT 60.0 SEC.

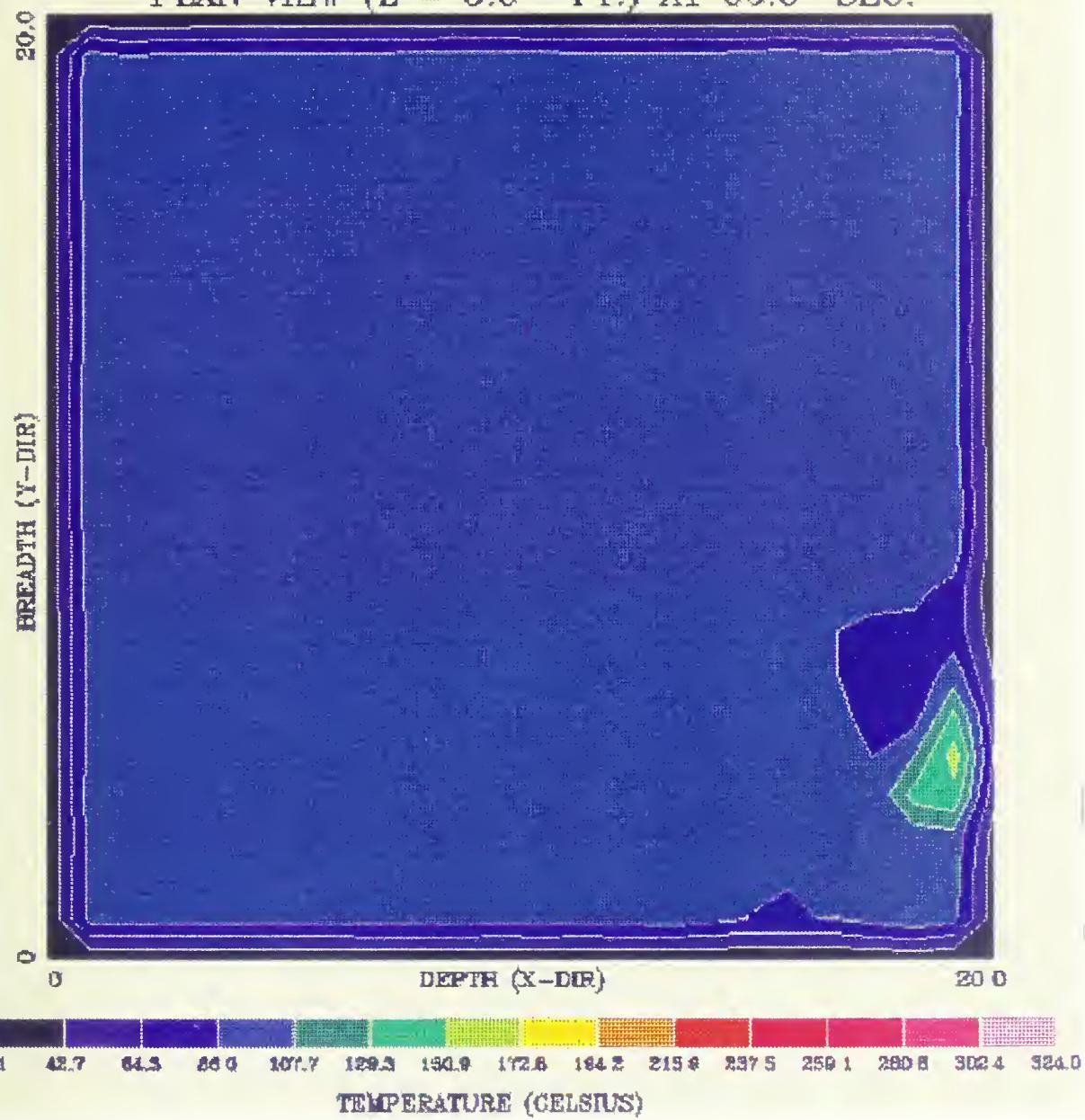


Figure 9. Temperature Profile, Plan View, 60 seconds.



PLAN VIEW (Z = 5.0 FT.) AT 90.0 SEC.

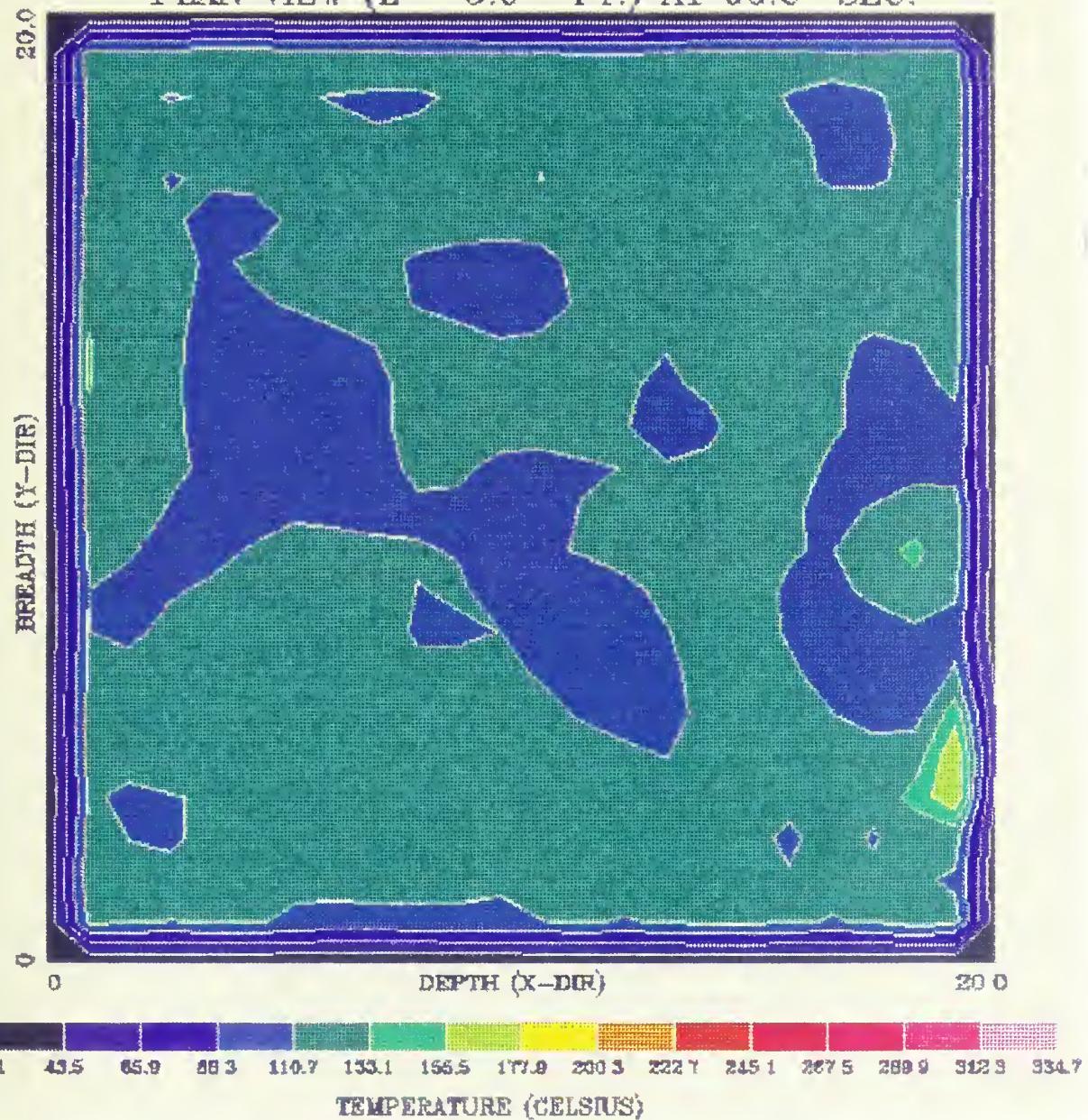


Figure 10. Temperature Profile, Plan View, 90 seconds.



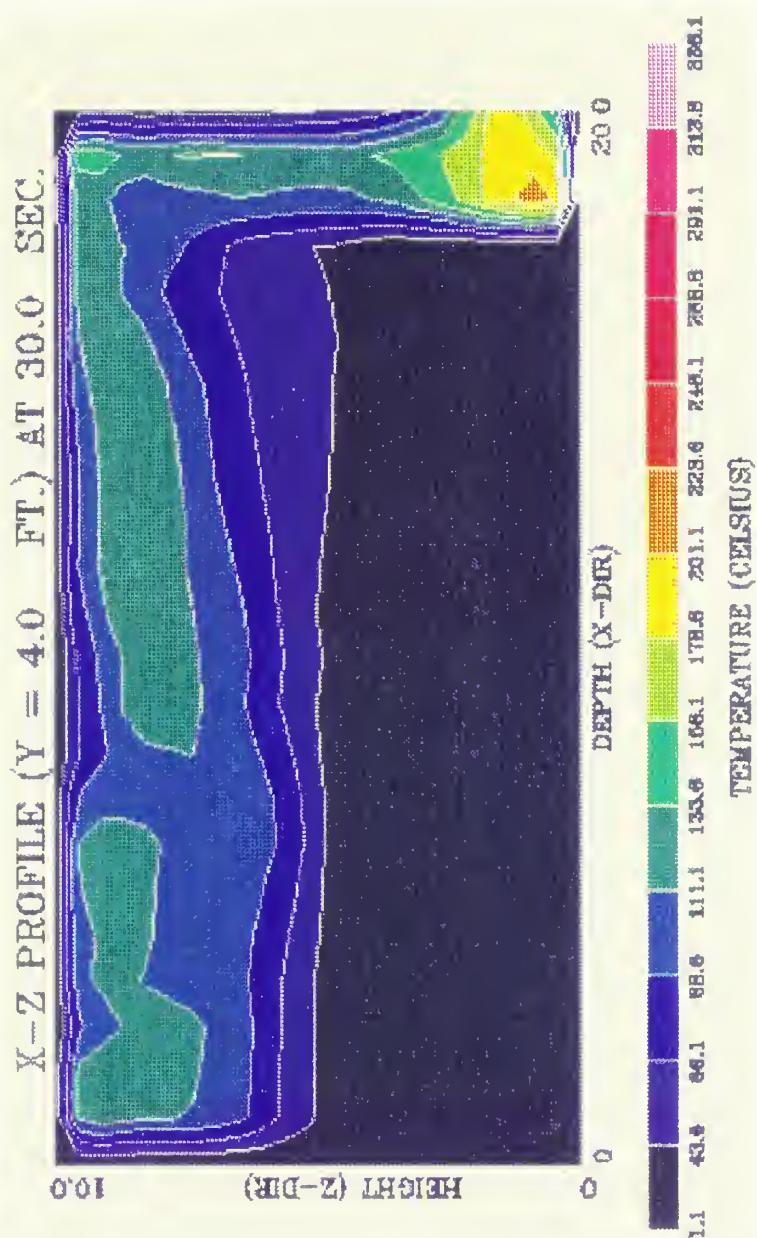


Figure 11. Temperature Profile, X-Z Profile, 30 seconds.



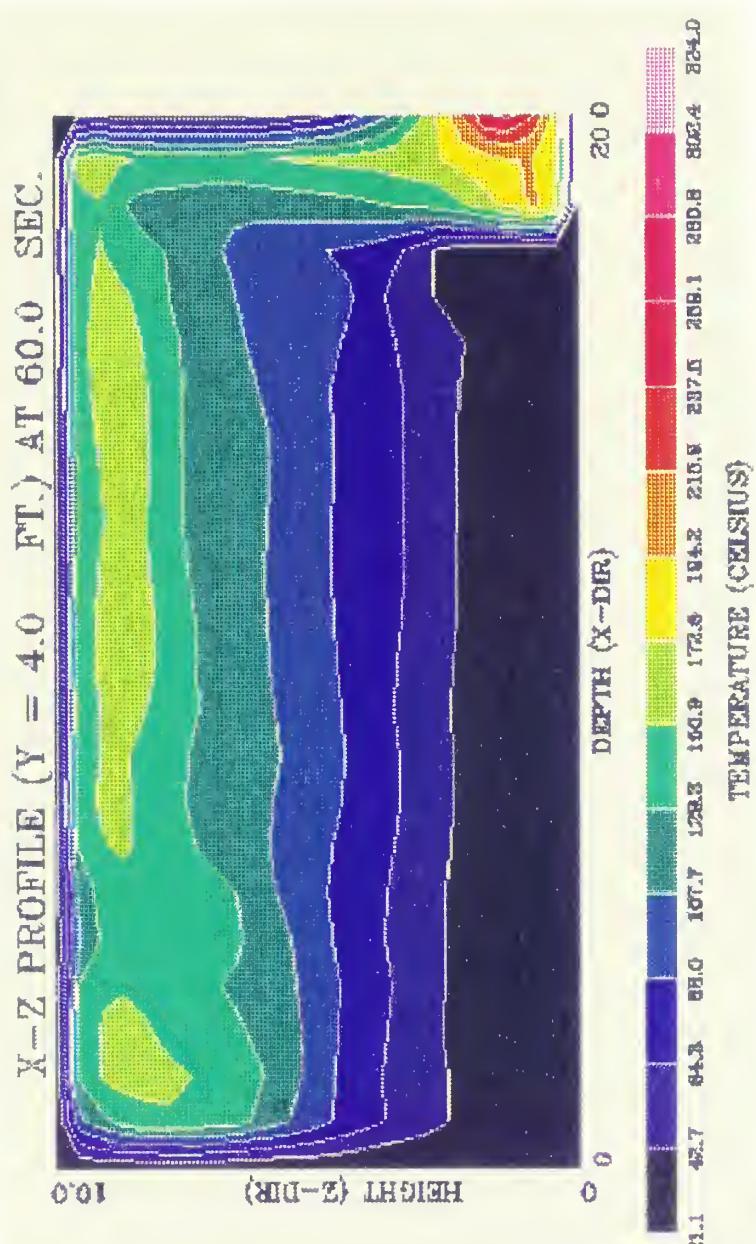


Figure 12. Temperature Profile, X-Z Profile, 60 seconds.



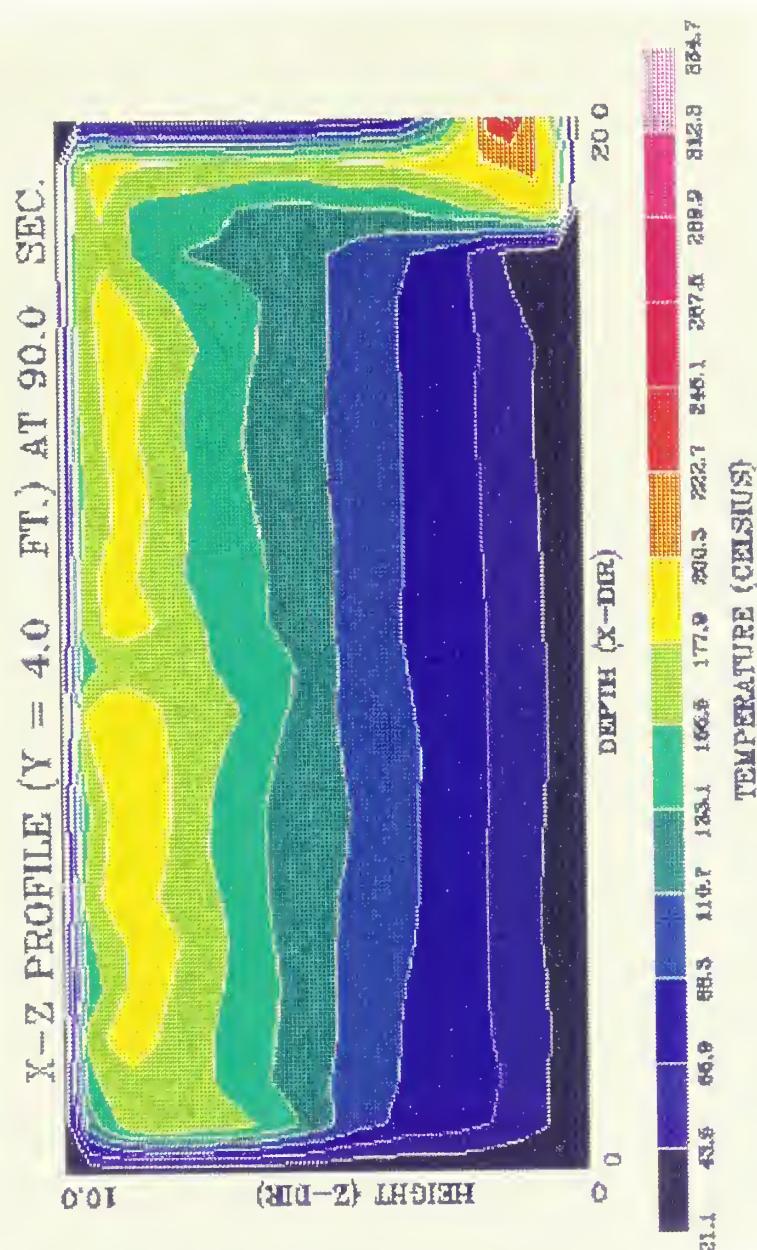


Figure 13. Temperature Profile, X-Z Profile, 90 seconds.



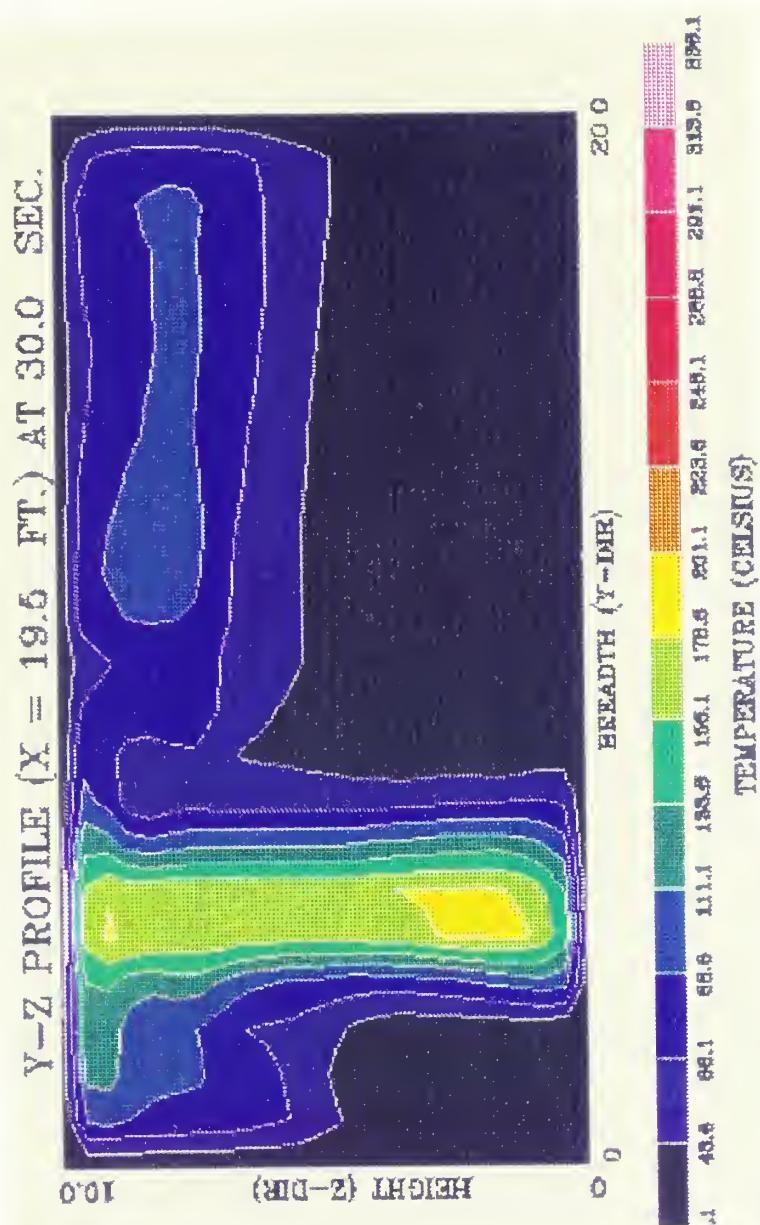


Figure 14. Temperature Profile, Y-Z Profile, 30 seconds.



Y-Z PROFILE (X = 19.5 FT.) AT 60.0 SEC.

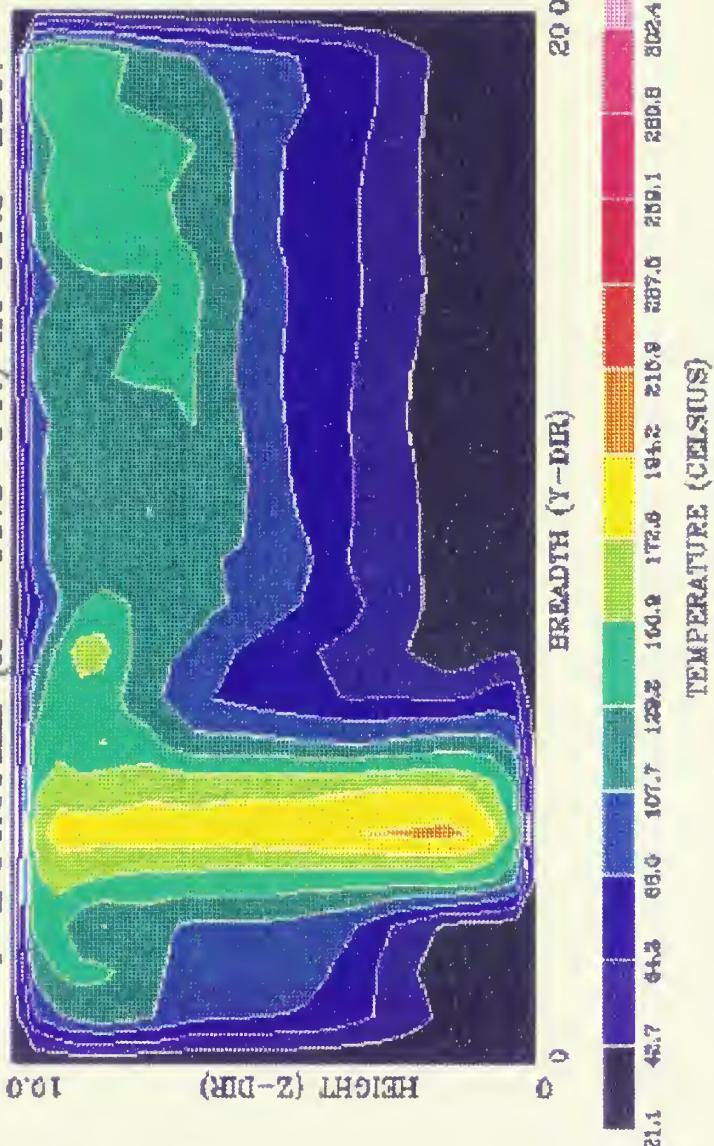


Figure 15. Temperature Profile, Y-Z Profile, 60 seconds.



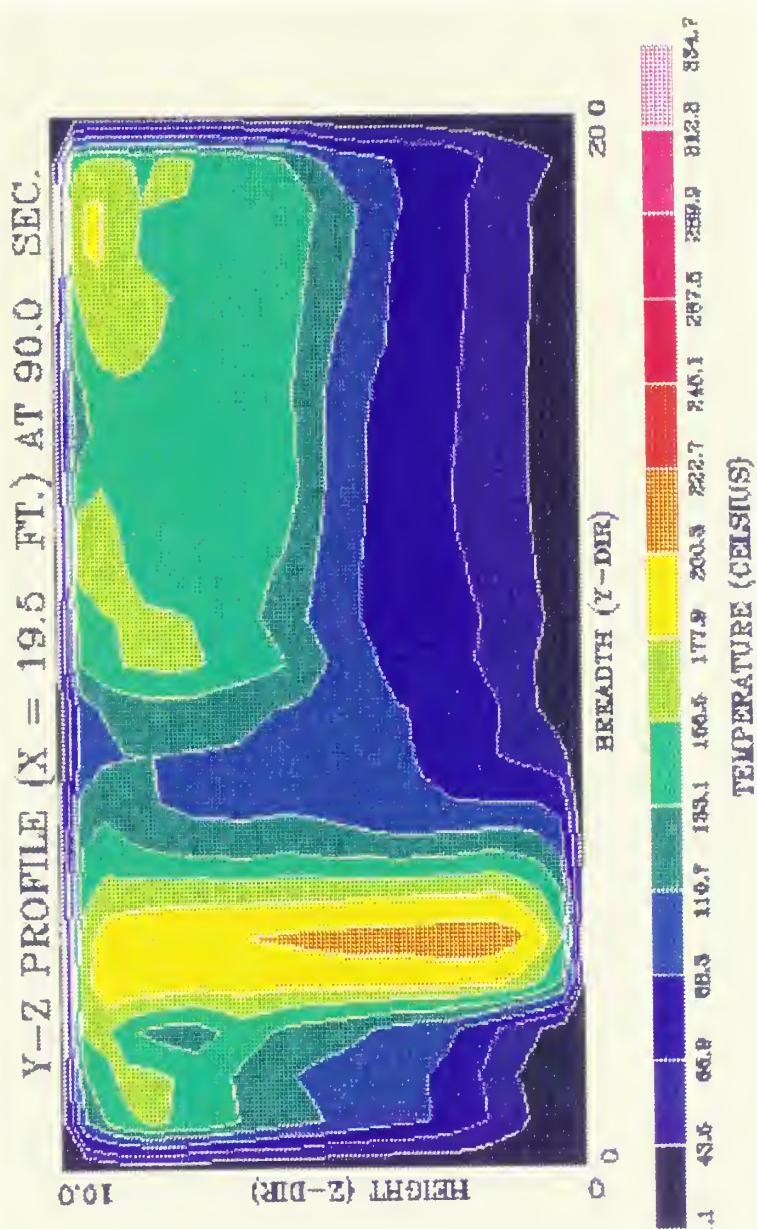
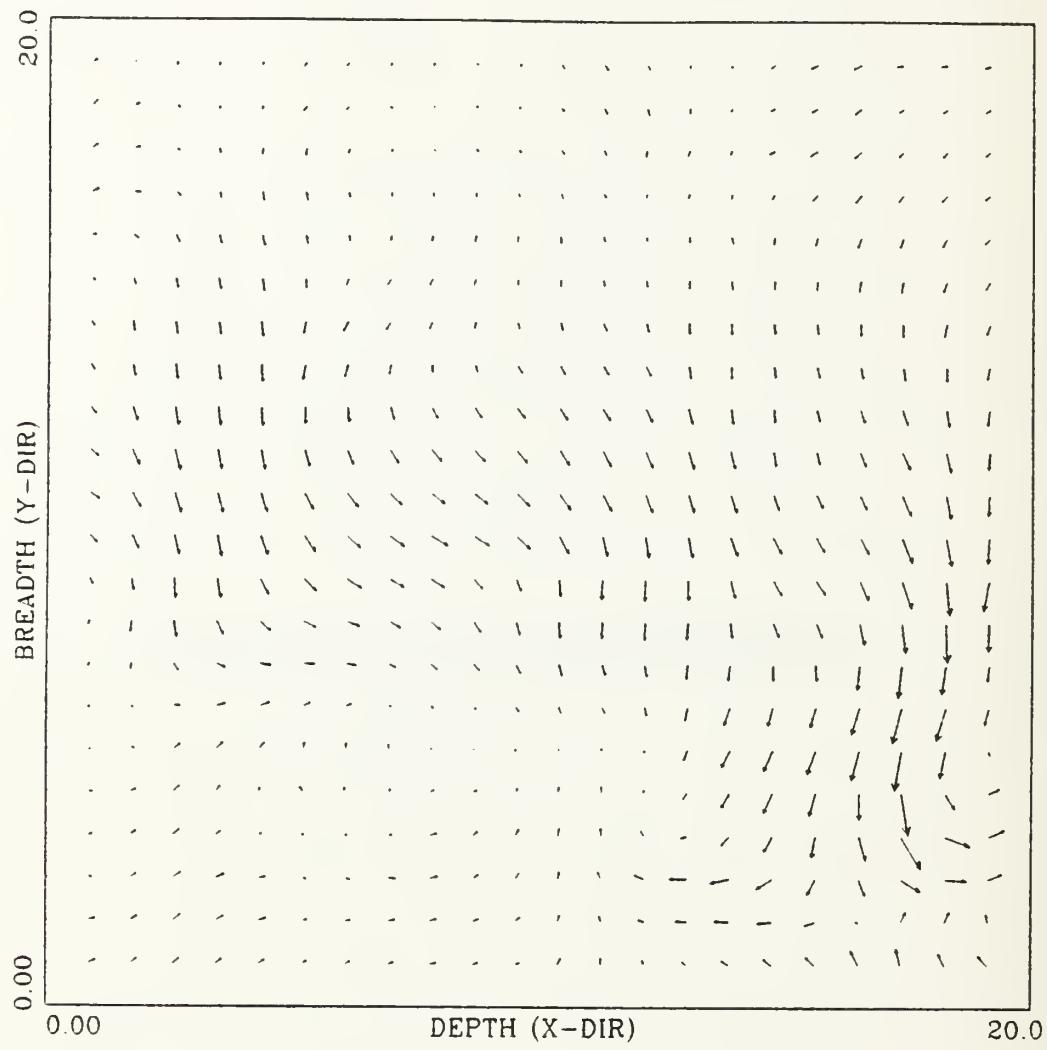


Figure 16. Temperature Profile, Y-Z Profile, 90 seconds.



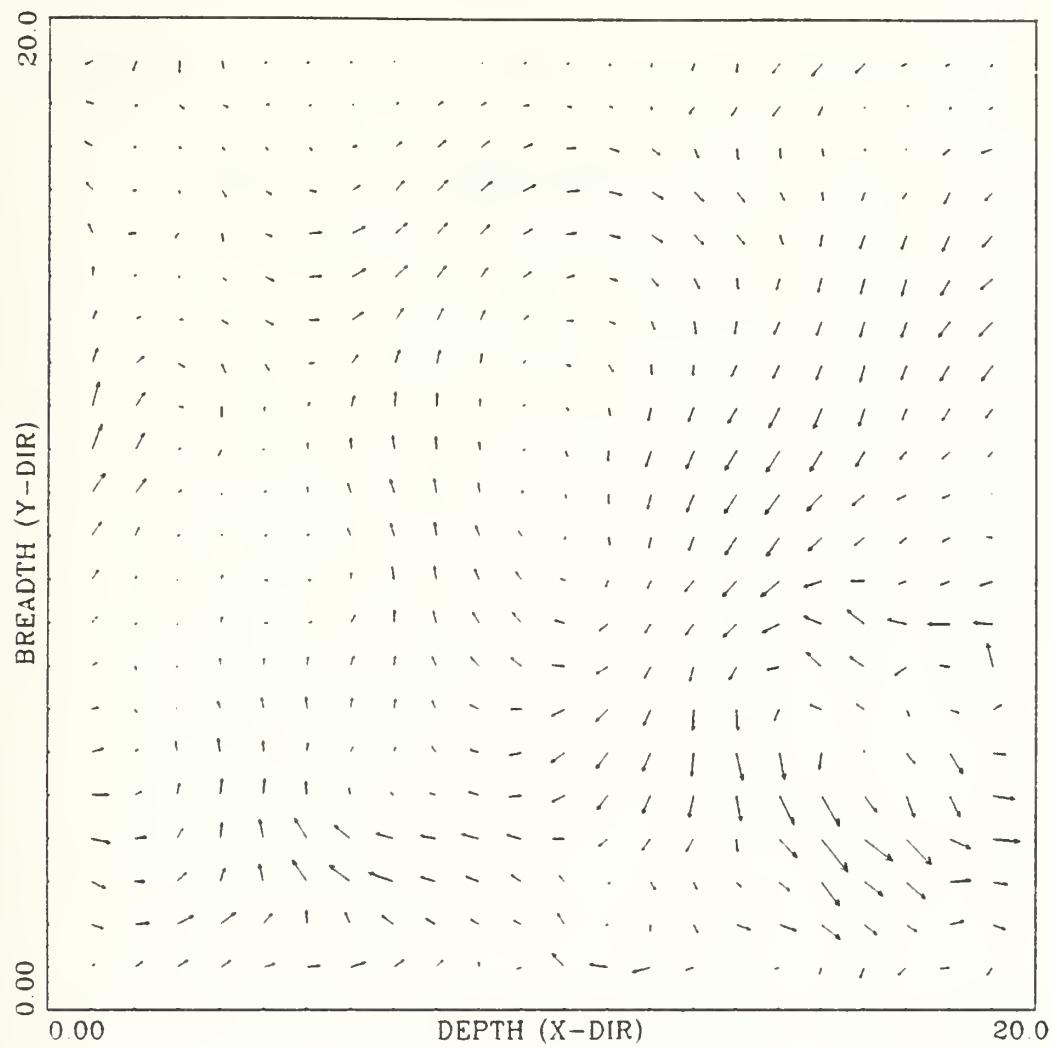
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PLAN VIEW (Z = 5.000 FT.) AT 30.00 SEC.

0.596E-02

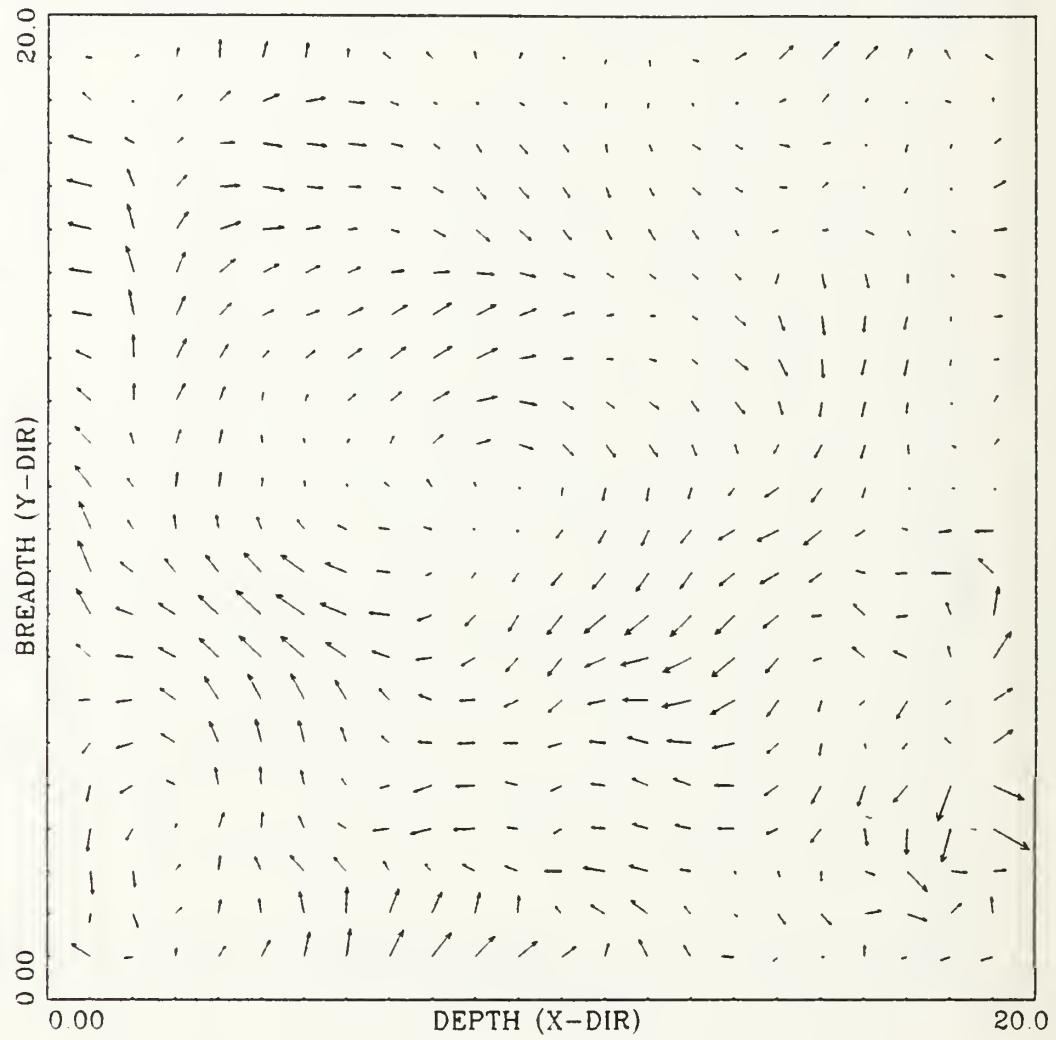
Figure 17. Velocity Profile, Plan View, 30 seconds.



PLAN VIEW ( $Z = 5.000$  FT.) AT 60.00 SEC.

0.324E+02

Figure 18. Velocity Profile, Plan View, 60 seconds.



PLAN VIEW (Z = 5.000 FT.) AT 90.00 SEC.

0.236E-02

Figure 19. Velocity Profile, Plan View, 90 seconds.

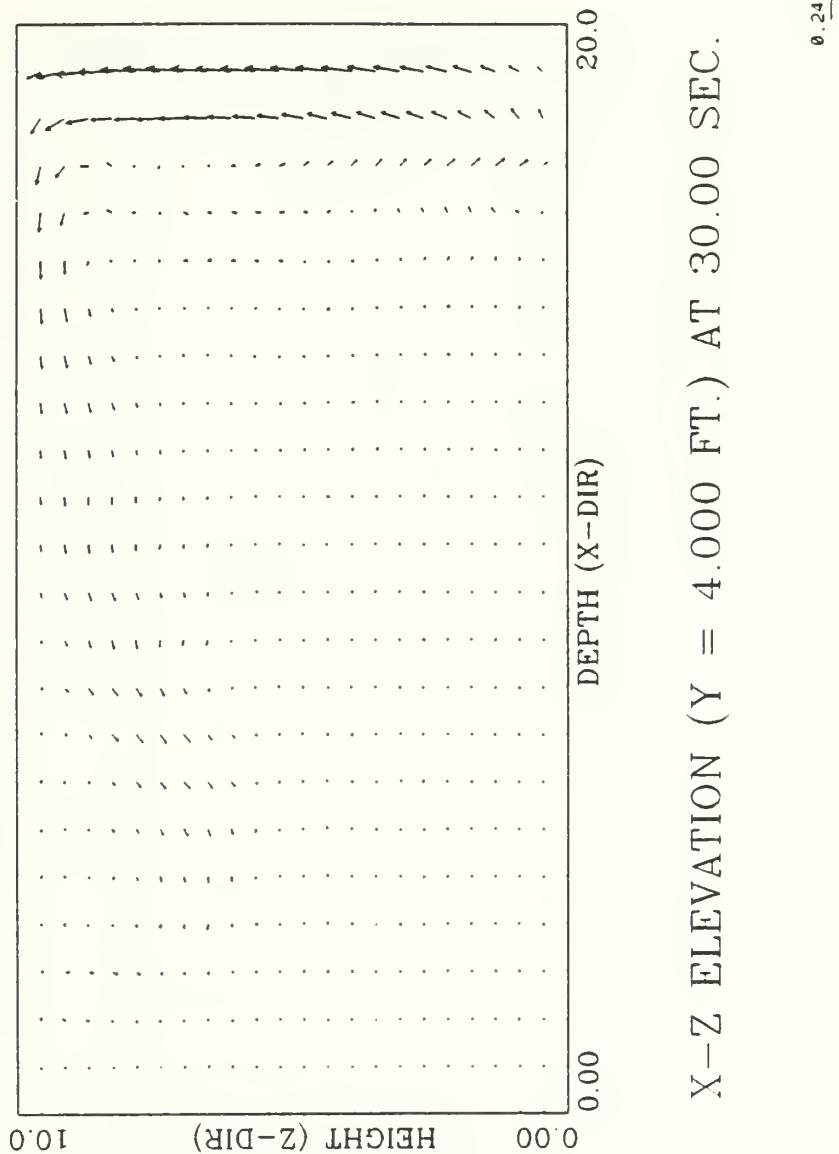


Figure 20. Velocity Profile, X-Z Profile, 30 seconds.

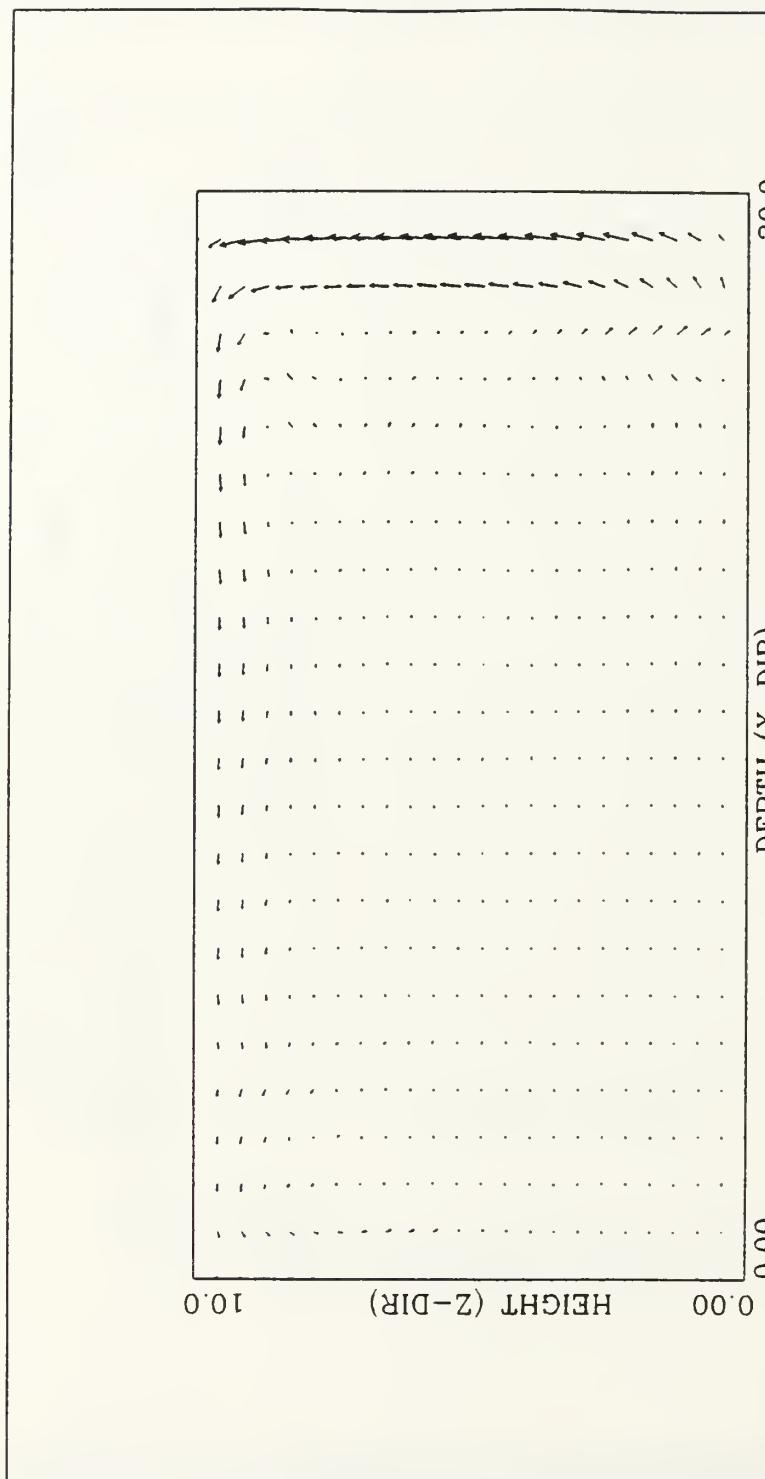
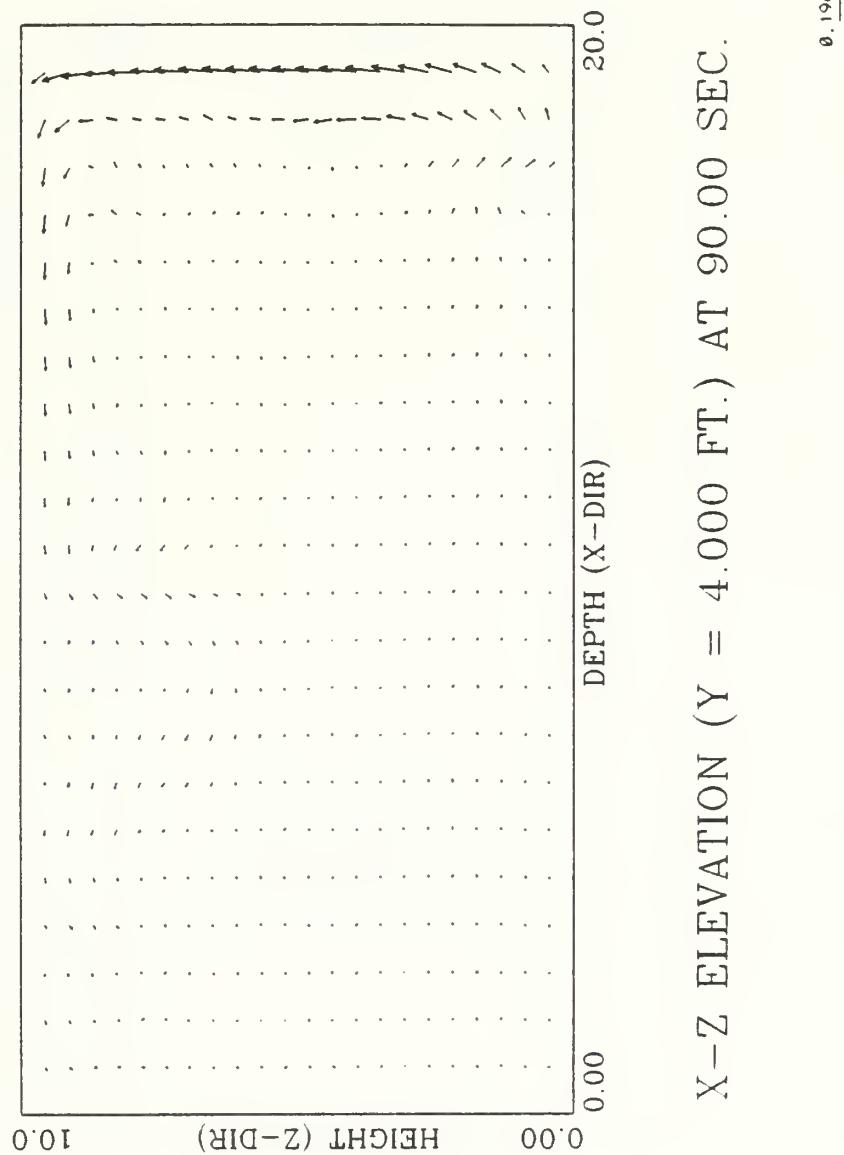
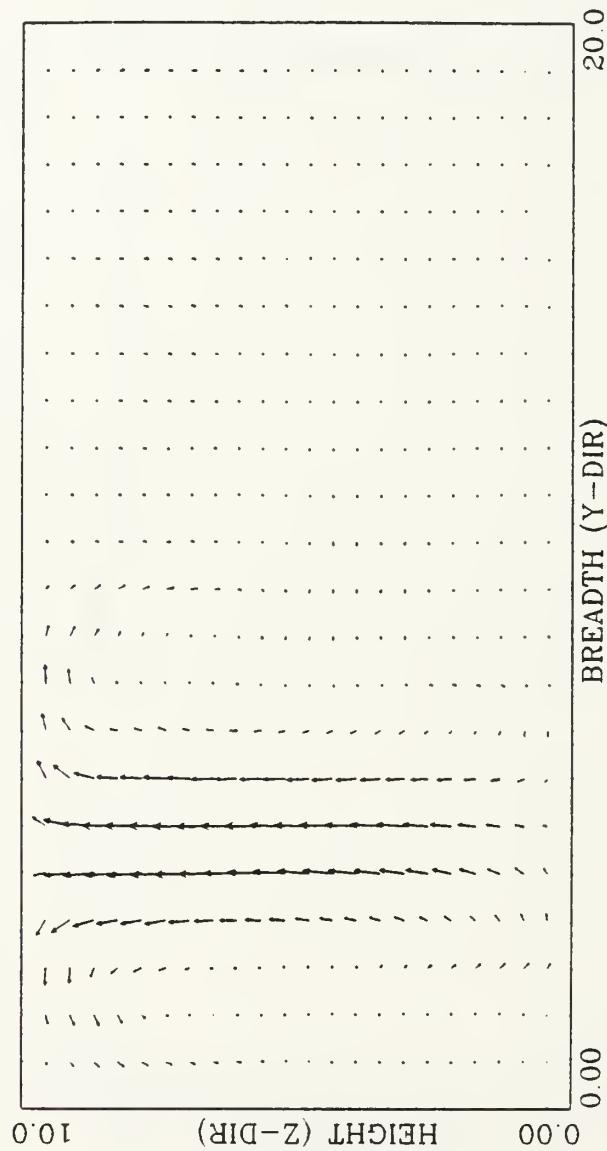


Figure 21. Velocity Profile, X-Z Profile, 60 seconds.



X-Z ELEVATION (Y = 4.000 FT.) AT 90.00 SEC.

Figure 22. Velocity Profile, X-Z Profile, 90 seconds.



Y-Z ELEVATION (X = 19.50 FT.) AT 30.00 SEC.

Figure 23. Velocity Profile, Y-Z Profile, 30 seconds.

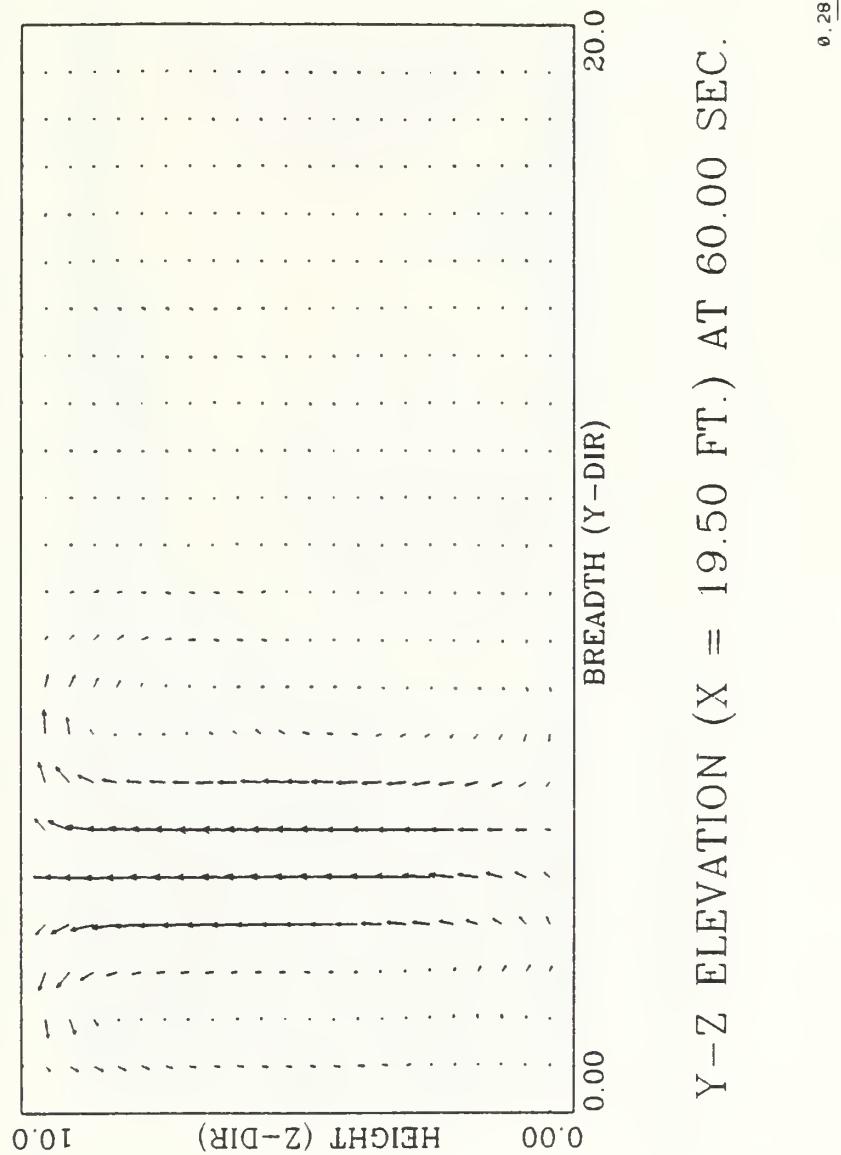


Figure 24. Velocity Profile, Y-Z Profile, 60 seconds.

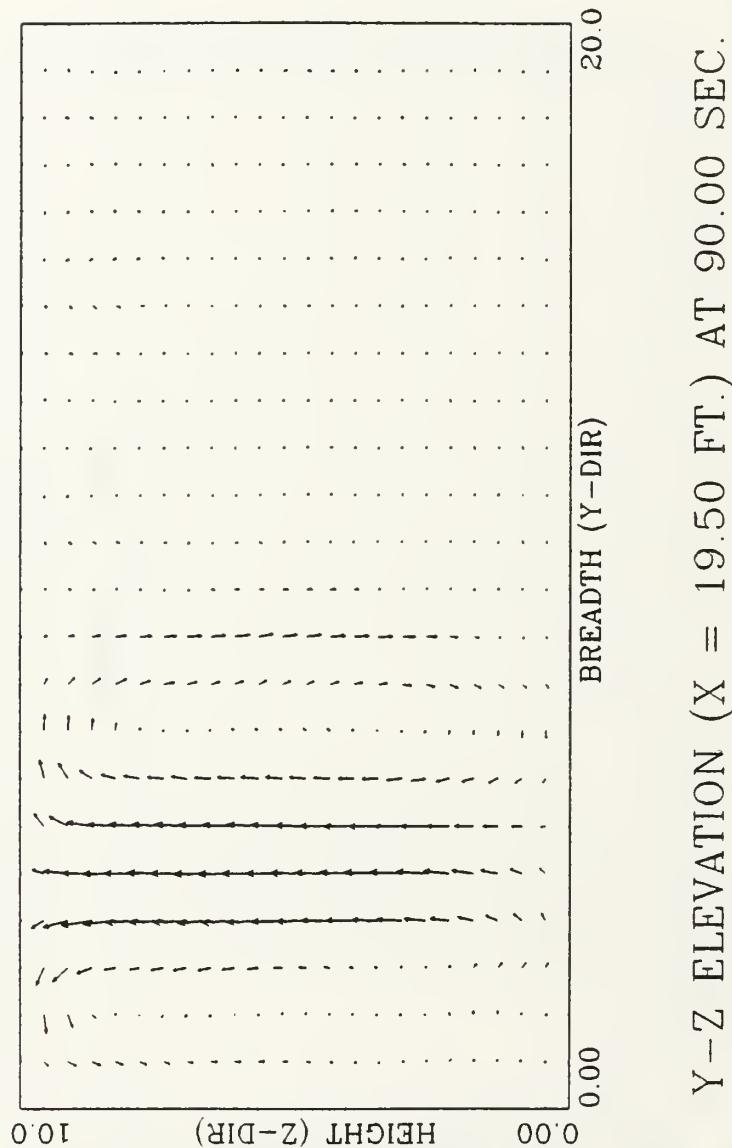


Figure 25. Velocity Profile, Y-Z Profile, 90 seconds.

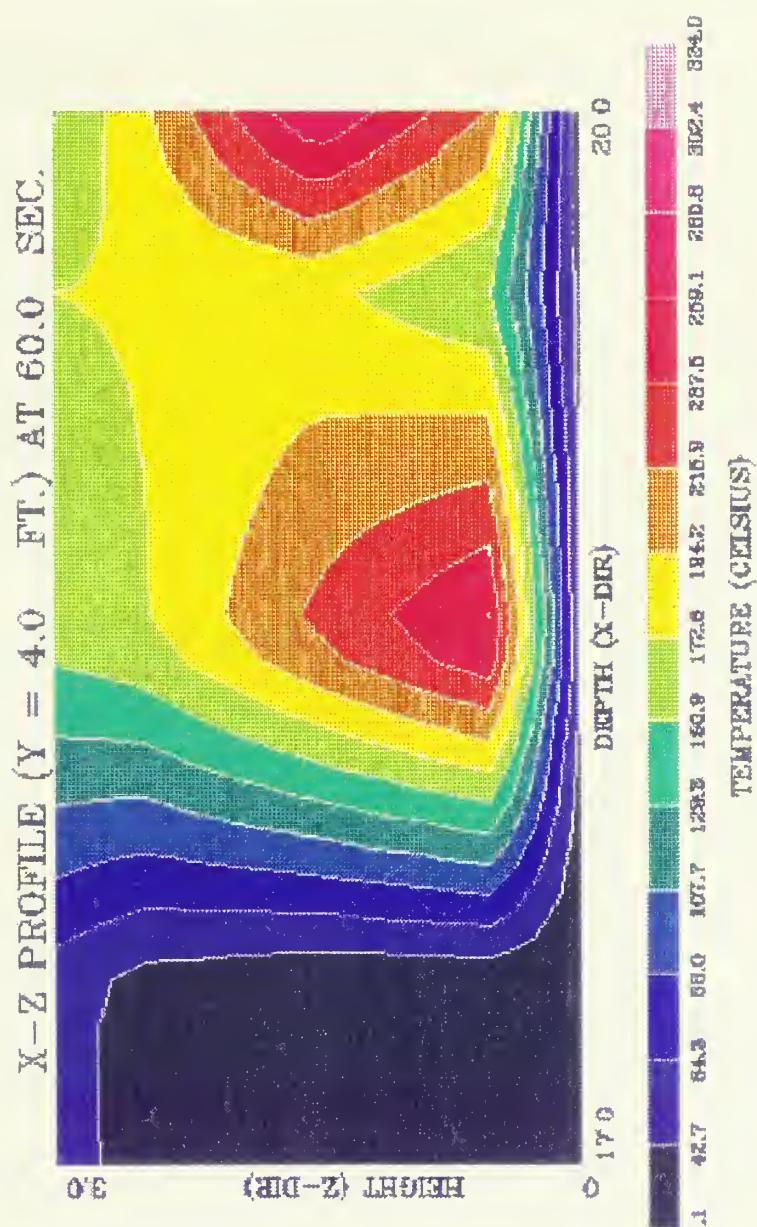
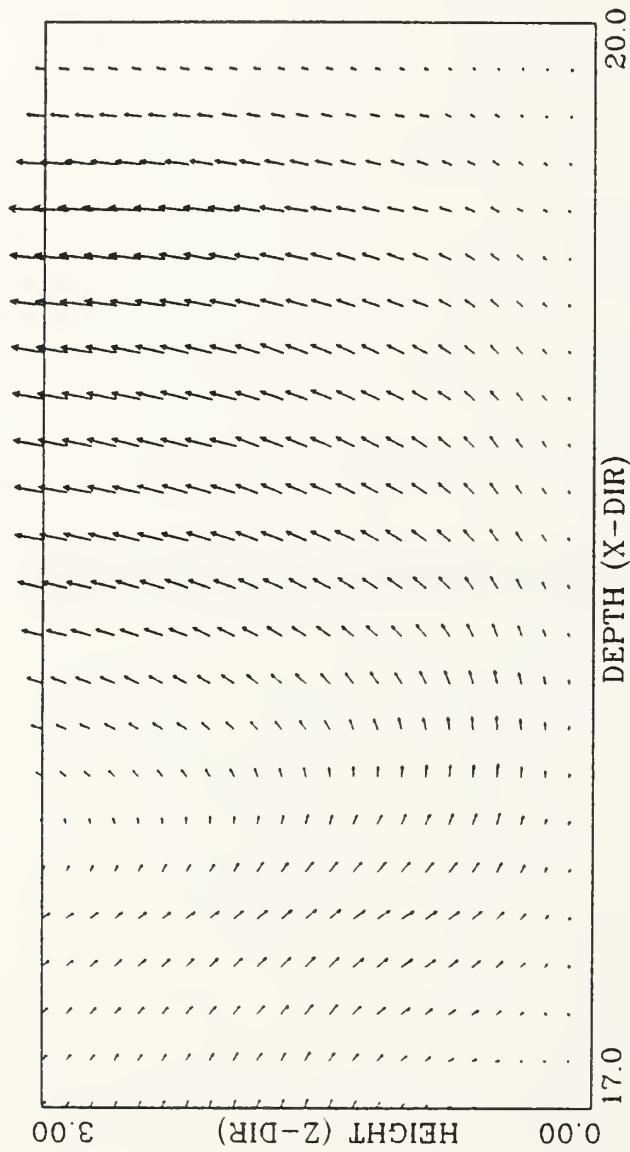


Figure 26. Example of "Zoom" feature of ISOTHERM.



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X-Z ELEVATION (Y = 4.000 FT.) AT 60.00 SEC.

Figure 27. Example of "Zoom" feature of VELOCITY.

## IV. CONCLUSIONS AND RECOMMENDATIONS

### A. CONCLUSIONS.

1. Program FIREBLD represents a marked improvement in user friendly data input to FIRE.
2. Additional improvements can be made in user friendliness of FIREBLD, and thus FIRE. Specifically, all locations and dimensions should be input as length measurements (i.e. feet or meters) by the user.
3. The burn rate used by SUBROUTINE CALQ in program FIRE is artificially low and must be increased before the code can be properly validated against actual test data.
4. The NCAR Graphics software provides increased flexibility in graphics output over the previously used graphics package.
5. The temperature and velocity profiles generated by this work appear to have the expected characteristics of an actual fire. Further testing and comparison to actual test data is necessary for validation of the code.
6. The ink jet printer used to create hard copy graphical printouts of the data in this work is slow and of marginal quality for professional publication. Improved graphics printing capabilities should be pursued.

### B. RECOMMENDATIONS.

1. Increase user friendliness of FIREBLD by putting all input in terms easily determined by the user. Specifically:
  - Input locations in terms of length measurements vice nodal locations.
  - User should have his choice of units (SI or English) when inputting data.
  - Input data should not require any manipulation by the user prior to entry.
2. Increase the burn rate used by SUBROUTINE CALQ in program FIRE to realistic levels and adjust size of time step as necessary to achieve stability.
3. Expand FIRE to completely model test chamber at the Naval Air Warfare Center, China Lake, CA. Specifically, include the natural vent and adjacent compartments.
4. Validate model against actual test procedures and results from Naval Air Warfare Center, China Lake.
5. Examine alternative graphical presentation schemes available with the NCAR Graphics software. Specifically, test feasibility of combining isotherm and velocity plots into single output. Also, examine use of NCAR Graphics movie making capabilities to provide a "real time" representation of data.
6. Enhance clarity of graphics printouts by procuring access to a laser quality color printing.

## APPENDIX A. PROGRAM FIREBLD

This program is used to build and/or modify the input data file required by the main program, FIRE.

PROGRAM FIREBLD

```
*****
**          THREE-DIMENSIONAL NUMERICAL SIMULATION          **
**          OF A FIRE SPREAD INSIDE A BUILDING          **
**          DEVELOPED BY :          **
**                  H.Q. YANG AND K.T. YANG          **
**          DEPARTMENT OF AEROSPACE & MECHANICAL ENGINEERING          **
**                  UNIVERSITY OF NOTRE DAME          **
**                  NOTRE DAME, INDIANA, 46556          **
**          DEC. 1986          **
**          AMMENDED BY          **
**                  K.J. THORKILDSEN          **
**                  LIEUTENANT, U.S. COAST GUARD          **
**          DEPARTMENT OF MECHANICAL ENGINEERING          **
**                  NAVAL POSTGRADUATE SCHOOL          **
**                  MONTEREY, CALIFORNIA 93942          **
**          SEP. 1992          **
*****
* THIS PROGRAM BUILDS AND/OR MODIFIES THE INPUT DATA FILE REQUIRED FOR *
* THE PROGRAM LISTED ABOVE. *
*****
*THIS SUBROUTINE SETS UP REQUIRED VALUES TO BEGIN THE PROGRAM.
*
*VARIABLES ARE:
* KRUN      = RESTART INDICATOR
* NCHIP     = NUMBER OF INTERNAL SOLID PIECES
* NMS       = NUMBER OF MASS SOURCES
* NWRP      = NUMBER OF TIME STEPS BETWEEN WRITES TO OUTPUT FILE
* NTHCO     = NUMBER OF THERMOCOUPLES TO PRINT OUT
* TMAX      = NONDIMENSIONAL MAXIMUM TIME ALLOWED
* XTMAX     = MAXIMUM TIME ALLOWED (SECONDS)
* TWRITE    = TIME BETWEEN FIELD VARIABLE OUTPUT (SECONDS)
* TTAPE     = TIME INTERVAL BETWEEN PLOTS (SECONDS)
* DTIME     = NONDIMENSIONAL TIME STEP
* XDTIME    = TIME STEP (SECONDS)
* HSTART    = FIRE START TIME (SECONDS)
* NHSZ(1,1) = STARTING NODE OF HEAT SOURCE, X-DIR
```

```

*  NHSZ(2,1) = Y-DIR
*  NHSZ(3,1) = Z-DIR
*  NHSZ(1,2) = ENDING NODE OF HEAT SOURCE, X-DIR
*  NHSZ(2,2) = Y-DIR
*  NHSZ(3,2) = Z-DIR
*  ICHPB = FIRST NODE OF INTERNAL SOLID IN X DIR
*  ICHPB = FIRST NODE OF INTERNAL SOLID IN X DIR
*  JCHPB = Y DIR
*  KCHPB = Z DIR
*  NCHPI = NUMBER OF INTERNAL SOLID NODES IN X DIR
*  NCHPJ = Y DIR
*  NCHPK = Z DIR
*  IMSB = FIRST MASS SOURCE NODE IN X DIR
*  JMSB = Y DIR
*  KMSB = Z DIR
*  NMSI = NUMBER OF MASS SOURCE NODES IN X DIR
*  NMSJ = Y DIR
*  NMSK = Z DIR
*  RMS = DIMENSIONLESS MASS SOURCE
*        (= CFM/(60.*H**2*U0*NMSI*NMSJ*NMSK))
*  CX,CY,CZ = THERMOCOUPLE POSITIONS IN X,Y,Z
*****DATA FILES USED IN THIS PROGRAM:
*
*      FILE # 10 = FIRE DATA B1 : INITIAL SET-UP DATA
*
*****
```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
CHARACTER ANS*1
LOGICAL L1
DIMENSION ICHPB(20),NCHPI(20),JCHPB(20),NCHPJ(20),KCHPB(20),
&          NCHPK(20),CPS(20),CONS(20),WFAN(20),IMSB(20),NMSI(20),
&          JMSB(20),NMSJ(20),KMSB(20),NMSK(20),RMS(20),CX(30),
&          CY(30),CZ(30),NHSZ(3,2)
PARAMETER (U0=1.0)
INQUIRE (FILE='FIRE DATA B1',EXIST=L1)
IF (L1) THEN
    PRINT *, 'INPUT DATA FILE FOUND!'
    PRINT *
    PRINT *, 'DO YOU WISH TO USE IT FOR INPUT?'
    READ (*,*) ANS
    IF (INDEX(ANS,'Y').GT.0.OR.INDEX(ANS,'y').GT.0) THEN
C *** READ IN DATA FROM EXISTING DATA FILE
        OPEN(10,FILE='FIRE DATA B1',STATUS='OLD')
        READ(10,*) X,Y,H,TFLR,TWAL,TA
        READ(10,*) NI,NJ,NK
        READ(10,*) NCHIP,NMS,NWRP,NTHCO
        READ(10,*) TMAX,DTIME,TTAPE,TWRITE,HSTART
        READ(10,*) NHSZ(1,1),NHSZ(1,2),NHSZ(2,1),NHSZ(2,2),
&                  NHSZ(3,1),NHSZ(3,2)
        IF (NCHIP.LE.0) GOTO 33
        DO 32 N=1,NCHIP
            READ(10,*) ICHPB(N),NCHPI(N),JCHPB(N),NCHPJ(N),KCHPB(N),
&                  NCHPK(N),CPS(N),CONS(N),WFAN(N)

```

```

32      CONTINUE
33      IF (NMS.LE.0) GOTO 37
      DO 36 N=1,NMS
          READ(10,*) IMSB(N),NMSI(N),JMSB(N),NMSJ(N),KMSB(N),
          & NMSK(N),RMS(N)
36      CONTINUE
37      DO 38 I=1,NTHCO
          READ (10,*) CX(I),CY(I),CZ(I)
38      CONTINUE

C *** UPDATE EXISTING DATA

C *** UPDATE COMPARTMENT DIMENSIONS
      PRINT *, 'CURRENT DATA:'
      PRINT *
      PRINT *, 'COMPARTMENT DIMENSIONS'
      PRINT *, ' LENGTH (X DIRECTION) : ',X,' FEET'
      PRINT *, ' WIDTH (Y DIRECTION) : ',Y,' FEET'
      PRINT *, ' HEIGHT (Z DIRECTION) : ',H,' FEET'
      PRINT *, ' WALL THICKNESS : ',TWAL,' INCHES'
      PRINT *, ' FLOOR/CEILING THICKNESS: ',TFLR,' INCHES'
      PRINT *
      PRINT *, 'DO YOU WISH TO CHANGE ANY OF THESE VALUES?'
      READ(5,*) ANS
      IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
          PRINT *, 'DO YOU WISH TO CHANGE THE LENGTH?'
          READ(5,*) ANS
          IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
              PRINT *, 'ENTER NEW LENGTH:'
              READ(5,*) X
          ENDIF
          PRINT *, 'DO YOU WISH TO CHANGE THE HEIGHT?'
          READ(5,*) ANS
          IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
              PRINT *, 'ENTER NEW HEIGHT:'
              READ(5,*) H
          ENDIF
          PRINT *, 'DO YOU WISH TO CHANGE THE WIDTH?'
          READ(5,*) ANS
          IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
              PRINT *, 'ENTER NEW WIDTH:'
              READ(5,*) Y
          ENDIF
          PRINT *, 'DO YOU WISH TO CHANGE THE WALL THICKNESS?'
          READ(5,*) ANS
          IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
              PRINT *, 'ENTER NEW WALL THICKNESS:'
              READ(5,*) TWAL
          ENDIF
          PRINT *,
          &      'DO YOU WISH TO CHANGE THE FLOOR/CEILING THICKNESS?'
          READ(5,*) ANS
          IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
              PRINT *, 'ENTER NEW FLOOR/CEILING THICKNESS:'
              READ(5,*) TFLR
          ENDIF

```

```

ENDIF

C **** UPDATE NUMBER OF CELLS
PRINT *
PRINT *, 'CURRENT DATA:'
PRINT *
PRINT *, 'NUMBER OF CELLS:'
PRINT *, '      X DIRECTION:    ',NI
PRINT *, '      Y DIRECTION:    ',NJ
PRINT *, '      Z DIRECTION:    ',NK
PRINT *
PRINT *, 'DO YOU WISH TO CHANGE ANY OF THESE VALUES?'
READ(5,*) ANS
IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
    PRINT *, 'DO YOU WISH TO CHANGE THE NUMBER OF X CELLS?'
    READ(5,*) ANS
    IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
        PRINT *, 'ENTER NUMBER OF X CELLS:'
        READ(5,*) NI
    ENDIF
    PRINT *, 'DO YOU WISH TO CHANGE THE NUMBER OF Y CELLS?'
    READ(5,*) ANS
    IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
        PRINT *, 'ENTER NUMBER OF Y CELLS:'
        READ(5,*) NJ
    ENDIF
    PRINT *, 'DO YOU WISH TO CHANGE THE NUMBER OF Z CELLS?'
    READ(5,*) ANS
    IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
        PRINT *, 'ENTER NUMBER OF Z CELLS:'
        READ(5,*) NK
    ENDIF
ENDIF
ENDIF

C **** UPDATE INTERNAL SOLIDS
PRINT *
PRINT *, 'CURRENT DATA:'
PRINT *
PRINT *, 'NUMBER OF INTERNAL SOLID PIECES:  ',NCHIP
IF(NCHIP.EQ.0) GOTO 42
PRINT *, 'PIECE STARTING NODES  NUMBER OF NODES  ',
        'THERMAL  SPECIFIC FAN'
& PRINT *, ' NO.      X      Y      Z      X      Y      Z      ',
        'CONDUCTIVITY  HEAT  SPEED'
& DO 40 N=1,NCHIP
    PRINT 2,'  ',N,ICHPB(N)-2,JCHPB(N)-2,KCHPB(N)-2,NCHPI(N),
        NCHPJ(N),NCHPK(N),CONS(N),CPS(N),WFAN(N)
2 FORMAT (2X,I3,2(4X,3(I3,1X)),4X,F9.4,2X,F8.4,2X,F5.1)
40 CONTINUE
42 PRINT *, 'DO YOU WISH TO CHANGE THE NUMBER OF SOLID PIECES?'
READ(5,*) ANS
IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
    PRINT *, 'ENTER NUMBER OF INTERNAL PIECES:'
    READ(5,*) NCHIP
ENDIF
IF(NCHIP.EQ.0) GOTO 44

```

```

PRINT *,
&   'DO YOU WISH TO CHANGE POSITION OF THE SOLID PIECES?'
READ(5,*) ANS
IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
  DO 46 N=1,NCHIP
    PRINT *, 'FOR SOLID PIECE NUMBER ',N,' ENTER THE'
    PRINT *, 'FIRST NODE IN EACH DIRECTION (X, Y AND Z)'
    READ(5,*) ICHPB(N),JCHPB(N),KCHPB(N)
    ICHPB(N)=ICHPB(N)+2
    JCHPB(N)=JCHPB(N)+2
    KCHPB(N)=KCHPB(N)+2
    PRINT *,
&   'NUMBER OF NODES IN EACH DIRECTION (X, Y AND Z)'
    READ(5,*) NCHPI(N),NCHPJ(N),NCHPK(N)
    PRINT *, 'THERMAL CONDUCTIVITY'
    READ(5,*) CONS(N)
    PRINT *, 'SPECIFIC HEAT'
    READ(5,*) CPS(N)
    PRINT *, 'AND FAN VELOCITY (0 IF NO FAN)'
    READ(5,*) WFAN(N)
46   CONTINUE
ENDIF

C **** UPDATE MASS SOURCE DATA
44   PRINT *
PRINT *, 'CURRENT DATA:'
PRINT *
PRINT *, 'NUMBER OF MASS SOURCES: ',NMS
IF(NMS.EQ.0) GOTO 50
PRINT *, 'SOURCE STARTING NODE NUMBER OF NODES FLOW'
PRINT *, ' NO.      X   Y   Z      X   Y   Z      RATE'
DO 52 N=1,NMS
  PRINT 4,N,IMSB(N)-2,JMSB(N)-2,KMSB(N)-2,NMSI(N),
    NMSJ(N),NMSK(N),
    RMS(N)*(60.*H**2*U0*NMSI(N)*NMSJ(N)*NMSK(N))
4   FORMAT (3X,I3,4X,2(3(1X,I3),4X),F5.1)
52   CONTINUE
50   PRINT *, 'DO YOU WISH TO CHANGE THE NUMBER OF SOURCES?'
READ(5,*) ANS
IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
  PRINT *, 'ENTER NUMBER OF SOURCES:'
  READ(5,*) NMS
ENDIF
IF(NMS.EQ.0) GOTO 54
PRINT *,
&   'DO YOU WISH TO CHANGE THE DATA FOR THE MASS SOURCES?'
READ(5,*) ANS
IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
  DO 56 N=1,NMS
    PRINT *
    PRINT *, 'FOR MASS SOURCE NUMBER ',N,' ENTER'
    PRINT *, 'FIRST NODE IN EACH DIRECTION (X, Y AND Z)'
    READ(5,*) IMSB(N),JMSB(N),KMSB(N)
    IMSB(N)=IMSB(N)+2
    JMSB(N)=JMSB(N)+2
    KMSB(N)=KMSB(N)+2

```

```

        PRINT *,
        &      'NUMBER OF NODES IN EACH DIRECTION (X, Y AND Z)'
        READ(5,*) NMSI(N),NMSJ(N),NMSK(N)
        PRINT *, 'THE FLOW RATE OF THE MASS SOURCE IN CFM'
        READ(5,*) RMS(N)
        RMS(N)=RMS(N)/(60.*H**2*U0*NMSI(N)*NMSJ(N)*NMSK(N))
56      CONTINUE
      ENDIF

C **** UPDATE THERMOCOUPLE DATA
54      PRINT *
      PRINT *, 'CURRENT DATA:'
      PRINT *
      PRINT *, 'NUMBER OF THERMOCOUPLES: ',NTHCO
      IF(NTHCO.EQ.0) GOTO 60
      PRINT *, 'TC          LOCATION'
      PRINT *, 'NO.      X      Y      Z'
      DO 62 N=1,NTHCO
      &      PRINT ('(1X,I2,2X,3(2X,F8.4))'),
      &      N,CX(N)*H,CY(N)*H,CZ(N)*H
52      CONTINUE
50      PRINT *, 'DO YOU WISH TO CHANGE THE NUMBER OF THERMOCOUPLES?'
      READ(5,*) ANS
      IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
      PRINT *, 'ENTER THE NUMBER OF THERMOCOUPLES:'
      READ(5,*) NTHCO
      ENDIF
      IF(NTHCO.EQ.0) GOTO 70
      IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) GOTO 65
      PRINT *, 'DO YOU WISH TO CHANGE THE THERMOCOUPLE LOCATIONS?'
      READ(5,*) ANS
      IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) GOTO 65
      GOTO 70
65      DO 66 N=1,NTHCO
      PRINT *, 'ENTER THE LOCATION (FEET) OF THERMOCOUPLE ',N
      READ(5,*) XCX,XCY,XCZ
      CX(N)=XCX/H
      CY(N)=XCY/H
      CZ(N)=XCZ/H
66      CONTINUE

C **** UPDATE HEAT SOURCE DATA
70      PRINT *
      PRINT *, 'CURRENT DATA'
      PRINT *
      PRINT *, 'HEAT SOURCE LOCATION'
      PRINT *, ' X DIRECTION: NODE',NHSZ(1,1)-2,' TO',NHSZ(1,2)-2
      PRINT *, ' Y DIRECTION: NODE',NHSZ(2,1)-2,' TO',NHSZ(2,2)-2
      PRINT *, ' Z DIRECTION: NODE',NHSZ(3,1)-2,' TO',NHSZ(3,2)-2
      PRINT *
      PRINT *, 'DO YOU WISH TO CHANGE THE STARTING COORDINATES?'
      READ(5,*) ANS
      IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
      PRINT *, 'ENTER THE STARTING COORDINATES:'
      PRINT *, '      X DIRECTION:'
      READ(5,*) NHSZ(1,1)

```

```

        PRINT *, ' Y DIRECTION:'
        READ(5,*) NHSZ(2,1)
        PRINT *, ' Z DIRECTION:'
        READ(5,*) NHSZ(3,1)
        DO 71 I=1,3
            NHSZ(I,1)=NHSZ(I,1)+2
71      CONTINUE
        ENDIF
        PRINT *, 'DO YOU WISH TO CHANGE THE ENDING COORDINATES?'
        READ(5,*) ANS
        IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
            PRINT *, 'ENTER THE ENDING COORDINATES:'
            PRINT *, ' X DIRECTION:'
            READ(5,*) NHSZ(1,2)
            PRINT *, ' Y DIRECTION:'
            READ(5,*) NHSZ(2,2)
            PRINT *, ' Z DIRECTION:'
            READ(5,*) NHSZ(3,2)
            DO 72 I=1,3
                NHSZ(I,2)=NHSZ(I,2)+2
72      CONTINUE
        ENDIF

C **** UPDATE AMBIENT TEMPERATURE
        PRINT *
        PRINT *, 'CURRENT DATA'
        PRINT *
        PRINT 3,
&        'AMBIENT TEMPERATURE =',TA-459.67,'DEGREES FARENHEIT'
3      FORMAT (1X,A,1X,F6.2,1X,A)
        PRINT *
        PRINT *, 'DO YOU WISH TO CHANGE THE AMBIENT TEMPERATURE?'
        READ(5,*) ANS
        IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
            PRINT *, 'ENTER THE NEW AMBIENT TEMPERATURE IN DEGREES F:'
            READ(5,*) TAF
            TA=TAF+459.67
        ENDIF

C *** UPDATE TIME DATA
        PRINT *
        PRINT *, 'CURRENT DATA'
        PRINT *
        PRINT *, 'MAXIMUM RUN TIME      =',TMAX*H/U0,' SECONDS'
        PRINT *, 'INCREMENTAL TIME STEP  =',DTIME*H/U0,' SECONDS'
        PRINT *, 'TIME BETWEEN DATA OUTPUT =',TWRITE,' SECONDS'
        PRINT *, 'TIME BETWEEN PLOTS      =',TTAPE,' SECONDS'
        PRINT *, 'FIRE START TIME        =',HSTART,' SECONDS'
        PRINT *
        PRINT *, 'DO YOU WISH TO CHANGE ANY OF THESE TIMES?'
        READ(5,*) ANS
        IF(INDEX(ANS,'Y').NE.0.OR.INDEX(ANS,'y').NE.0) THEN
            PRINT *, 'ENTER MAXIMUM RUN TIME IN SECONDS:'
            READ(5,*) XTMAX
            TMAX=XTMAX*U0/H
            PRINT *, 'INCREMENTAL TIME STEP IN SECONDS:'

```

```

READ(5,*) XDTIME
DTIME=XDTIME*U0/H
PRINT *, 'TIME BETWEEN DATA OUTPUT IN SECONDS: '
READ(5,*) TWRITE
PRINT *, 'TIME BETWEEN PLOTS IN SECONDS: '
READ(5,*) TTAPE
PRINT *, 'FIRE START TIME IN SECONDS: '
READ(5,*) HSTART
NWRP=INT(TWRITE/XDTIME)/2
ENDIF
ELSE
    PRINT *, 'PROGRAM TERMINATING.'
    PRINT *, 'PLEASE RENAME FIRE.DAT AND TRY AGAIN.'
    GOTO 999
ENDIF

```

\*\*\*\*\* CREATING NEW DATA FILE

```

ELSE
    PRINT *, 'FIRE DATA B1 NOT FOUND!'
    PRINT *, 'CREATING NEW DATA FILE.'
    OPEN(10,FILE='/FIRE DATA B1',STATUS='NEW')

```

\*\*\*\*\* INPUT NEW DATA \*\*\*\*\*

C \*\*\* INPUT GEOMETRIC DATA

```

    PRINT *, 'INPUT COMPARTMENT LENGTH (X DIRECTION) IN FEET'
    READ(5,*) X
    PRINT *, 'INPUT COMPARTMENT HEIGHT (Z DIRECTION) IN FEET'
    READ(5,*) H
    PRINT *, 'INPUT COMPARTMENT WIDTH (Y DIRECTION) IN FEET'
    READ(5,*) Y
    PRINT *, 'INPUT COMPARTMENT WALL THICKNESS IN INCHES'
    READ(5,*) TWAL
    PRINT *, 'INPUT COMPARTMENT FLOOR/CEILING THICKNESS IN INCHES'
    READ(5,*) TFLR
    PRINT *, 'INPUT NUMBER OF CELLS IN THE X DIRECTION: '
    READ(5,*) NI
    PRINT *, 'INPUT NUMBER OF CELLS IN THE Y DIRECTION: '
    READ(5,*) NJ
    PRINT *, 'INPUT NUMBER OF CELLS IN THE Z DIRECTION: '
    READ(5,*) NK

```

C \*\*\* INPUT INTERNAL SOLIDS DATA

```

    PRINT *, 'INPUT NUMBER OF INTERNAL SOLID PIECES'
    READ(5,*) NCHIP
    IF (NCHIP.GT.0) THEN
        PRINT *, 'INPUT THE LOCATION OF INTERNAL SOLID PIECES'
        DO 14 N=1,NCHIP
            PRINT *
            PRINT *, 'FOR SOLID PIECE NUMBER ',N,' ENTER THE'
            PRINT *, 'FIRST NODE IN EACH DIRECTION (X, Y AND Z)'
            READ(5,*) ICHPB(N),JCHPB(N),KCHPB(N)
            ICHPB(N)=ICHPB(N)+2
            JCHPB(N)=JCHPB(N)+2
            KCHPB(N)=KCHPB(N)+2

```

```

        PRINT *, 'NUMBER OF NODES IN EACH DIRECTION (X, Y AND Z)'
        READ(5,*) NCHPI(N),NCHPJ(N),NCHPK(N)
        PRINT *, 'THERMAL CONDUCTIVITY'
        READ(5,*) CONS(N)
        PRINT *, 'SPECIFIC HEAT'
        READ(5,*) CPS(N)
        PRINT *, 'AND FAN VELOCITY (0 IF NO FAN)'
        READ(5,*) WFAN(N)
14      CONTINUE
ENDIF

C **** INPUT MASS SOURCE DATA
        PRINT *, 'INPUT NUMBER OF MASS SOURCES'
        READ(5,*) NMS
        IF (NMS.EQ.0) THEN
            PRINT *
            PRINT *, 'ENTER MASS SOURCE DATA:'
            DO 18 N=1,NMS
                PRINT *, 'FIRST NODE IN EACH DIRECTION (X, Y AND Z)'
                READ(5,*) IMSB(N),JMSB(N),KMSB(N)
                IMSB(N)=IMSB(N)+2
                JMSB(N)=JMSB(N)+2
                KMSB(N)=KMSB(N)+2
                PRINT *, 'NUMBER OF NODES IN EACH DIRECTION (X, Y AND Z)'
                READ(5,*) NMSI(N),NMSJ(N),NMSK(N)
                PRINT *, 'THE FLOW RATE OF THE MASS SOURCE IN CFM'
                READ(5,*) RMS(N)
                RMS(N)=RMS(N)/(60.*H**2*U0*NMSI(N)*NMSJ(N)*NMSK(N))
18      CONTINUE
ENDIF

C **** INPUT THERMOCOUPLE DATA
        PRINT *, 'INPUT NUMBER OF THERMOCOUPLES'
        READ(5,*) NTHCO
        PRINT *, 'INPUT THERMOCOUPLE POSITION IN FEET:'
        DO 19 I=1,NTHCO
            PRINT *
            PRINT *, 'FOR THERMOCOUPLE NUMBER ',I
            PRINT *, '          X POSITION (FEET):'
            READ (5,*) XCX
            CX(I)=XCX/H
            PRINT *, '          Y POSITION (FEET):'
            READ (5,*) XCY
            CY(I)=XCY/H
            PRINT *, '          Z POSITION (FEET):'
            READ (5,*) XCZ
            CZ(I)=XCZ/H
19      CONTINUE

C **** INPUT HEAT SOURCE DATA
        PRINT *, 'INPUT FIRST NODE OF HEAT SOURCE '
        PRINT *, '          X DIRECTION:'
        READ (5,*) NHSZ(1,1)
        PRINT *, '          Y DIRECTION:'
        READ (5,*) NHSZ(2,1)
        PRINT *, '          Z DIRECTION:'

```

```

READ (5,*) NHSZ(3,1)
PRINT *, 'INPUT LAST NODE OF HEAT SOURCE IN EACH DIRECTION:'
PRINT *, '          X DIRECTION:'
READ (5,*) NHSZ(1,2)
PRINT *, '          Y DIRECTION:'
READ (5,*) NHSZ(2,2)
PRINT *, '          Z DIRECTION:'
READ (5,*) NHSZ(3,2)

C **** CORRECT HEAT SOURCE LOCATION DUE TO EXTERNAL CELLS
DO 5 I=1,3
    DO 6 J=1,2
        NHSZ(I,J)=NHSZ(I,J)+2
6    CONTINUE
5    CONTINUE

C **** INPUT AMBIENT TEMPERATURE
PRINT *, 'INPUT AMBIENT TEMPERATURE (DEGREES FARENHEIT)'
READ(5,*) TAF
TA=TAF+459.67

C **** INPUT TIME DATA
PRINT *, 'INPUT MAX RUN TIME FOR FIRE (SECONDS)'
READ(5,*) XTMAX
TMAX=XTMAX*U0/H
PRINT *, 'INPUT SIZE OF TIME STEP (SECONDS)'
READ(5,*) XDTIME
DTIME=XDTIME*U0/H
PRINT *, 'INPUT FIRE START TIME (SECONDS)'
READ(5,*) HSTART
PRINT *, 'INPUT TIME INTERVAL BETWEEN DATA SAVES (SECONDS)'
READ(5,*) TWRITE
PRINT *, 'INPUT TIME INTERVAL BETWEEN PLOTS (SECONDS)'
READ(5,*) TTape

C **** DETERMINE NWRP AND ADJUST TWRITE
NWRP=INT(TWRITE/XDTIME)/2
ENDIF

C **** SAVE DATA IN DATA FILE
REWIND(10)
WRITE(10,*) X,Y,H,TFLR,TWAL,TA
WRITE(10,*) NI,NJ,NK
WRITE(10,*) NCHIP,NMS,NWRP,NTHCO
WRITE(10,*) TMAX,DTIME,TTape,TWRITE,HSTART
WRITE(10,*) NHSZ(1,1),NHSZ(1,2),NHSZ(2,1),NHSZ(2,2),NHSZ(3,1),
&           NHSZ(3,2)
IF (NCHIP.EQ.0) GOTO 20
DO 22 N=1,NCHIP
    WRITE(10,*) ICHPB(N),NCHPI(N),JCHPB(N),NCHPJ(N),KCHPB(N),
    &           NCHPK(N),CPS(N),CONS(N),WFAN(N)
22 CONTINUE
20 IF (NMS.EQ.0) GOTO 24
    DO 26 N=1,NMS
        WRITE(10,*) IMSB(N),NMSI(N),JMSB(N),NMSJ(N),KMSB(N),
    &           NMSK(N),RMS(N)

```

```
26 CONTINUE
24 DO 28 I=1,NTHCO
      WRITE(10,*) CX(I),CY(I),CZ(I)
28 CONTINUE
      REWIND(10)
      CLOSE(10)

999 END
```

## APPENDIX B. PROGRAM FIRE

### PROGRAM FIRE

```
*****
** PROGRAM FIRE
** THREE-DIMENSIONAL NUMERICAL SIMULATION
** OF A FIRE SPREAD INSIDE A BUILDING
** DEVELOPED BY :
** H.Q. YANG AND K.T. YANG
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** DEC. 1986
** AMMENDED BY
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** SEP. 1992
*****
*SET CONSTANTS:
* CPO : REFERENCE SPECIFIC HEAT OF AIR =
* GC : GRAVITATIONAL ACCELERATION = 32.17 FT/SEC**2
* RAIR : UNIVERSAL GAS CONSTANT FOR AIR = 53.34
* RHOO : REFERENCE AIR DENSITY (LBM/FT**3) = 0.0714 LBM/FT**3
* U0 : REFERENCE VELOCITY (FT/SEC) = 1.0 FT/SEC
*
*COMPARTMENT DIMENSIONS (IN FEET):
* H : HEIGHT IN Z-DIRECTION (USED AS REFERENCE LENGTH)
* X : LENGTH IN X-DIRECTION
* Y : WIDTH IN Y-DIRECTION
*
* NI : NUMBER OF CELLS IN X-DIRECTION
* NJ : Y-DIRECTION
* NK : Z-DIRECTION
*
* CONSRA : TA**3/(RA*CP*U0**H**H)
* HCONV : HEAT TRANSFER COEFFICIENT TO THE AMBIENT (BTU/H*K*FT**2)
* TA : REFERENCE TEMPERATURE (R)
* TINIT : INITIAL TEMPERATURE (0)
* UR : REFERENCE VELOCITY (CM/S)
*
*HEAT SOURCE DATA:
* NHSZ(1,1) : STARTING CONTROL VOLUME NUMBER IN X-DIRECTION
* NHSZ(2,1) : Y-DIRECTION
```

```

* NHSZ(3,1) : Z-DIRECTION
* NHSZ(1,2) : LAST CONTROL VOLUME NUMBER IN X-DIRECTION
* NHSZ(2,2) : Y-DIRECTION
* NHSZ(3,2) : Z-DIRECTION
*
*INTERNAL SOLID PIECES:
* NCHIP : NUMBER OF INTERNAL SOLID PIECES
* ICHPB() : STARTING NODE NUMBER FOR SOLID IN X-DIRECTION
* JCHPB() : Y-DIRECTION
* KCHPB() : Z-DIRECTION
* NCHPI() : NUMBER OF NODES OF SOLID IN X-DIRECTION
* NCHPJ() : Y-DIRECTION
* NCHPK() : Z-DIRECTION
*
*TOTAL HEAT:
* QSIN : INPUT FROM THE FIRE
* QSWAL : LOST TO THE WALL (FROM AIR TO THE WALL)
* QSFAN : CARRIED AWAY BY THE VENTILATION
*
*VIEW FACTORS FROM HEAT SOURCE:
* VFHSE(N,J,K) : TO ELEMENT J,K ON WEST WALL
* VFHSE(N,J,K) : EAST WALL
* VFHSN(N,K,I) : TO ELEMENT K,I ON NORTH WALL
* VFHSS(N,K,I) : SOUTH WALL
* VFHSF(N,I,J) : TO ELEMENT I,J ON FRONT WALL
* VFHSB(N,I,J) : BACK WALL
*****
*DATA FILES USED IN THIS PROGRAM:
*
* FILE # 10 = FIRE DATA : INITIAL SET-UP DATA
*           11 = CONTINUE DATA : RESTART/CONTINUATION DATA
*           12 = OUTPUT DATA : OUTPUT RESULTS
*           13 = PLOT DATA : DATA FOR PLOTTING
*****
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(25),YC(25),ZC(25),XS(25),YS(25),ZS(25),DXXC(25),
&          DYYC(25),DZZC(25),DXXS(25),DYYS(25),DZZS(25)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL2/X,Y,H,TFLR,TWAL
COMMON/BL3/F,FR,HSTART
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL12/NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER
COMMON/BL14/HCOEF,CNT,ABTURB,BTURB,VISL,VISMAX
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,COND0,VIS0,RHO0,
&          TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL20/SIG11(25,25,15),SIG12(25,25,15),SIG22(25,25,15),
&          SIG13(25,25,15),SIG23(25,25,15),SIG33(25,25,15)
COMMON/BL23/RMS(20),NMS,IMSB(20),NMSI(20),JMSB(20),NMSJ(20),
&          KMSB(20),NMSK(20)
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
&          JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),
&          COD(25,25,15),UOD(25,25,15),VOD(25,25,15),
&          WOD(25,25,15)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),

```

```

& U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL33/TPD(25,25,15),RPD(25,25,15),PPD(25,25,15),
& CPD(25,25,15),UPD(25,25,15),VPD(25,25,15),
& WPD(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
& SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
& DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
& AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
& SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
& CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)
COMMON/BL38/TCOUP(30),CX(30),CY(30),CZ(30),NTH(30,3),NTHCO
COMMON/BL39/ALEW,CONSRA,QSIN,QSWER,QSWAL,QSAIR,QSFAN
COMMON/BL40/VFHSE(5,25,15),VFHSS(5,25,15),VFHSS(5,15,25),
& VFHSN(5,15,25),VFHSB(5,25,25),VFHSF(5,25,25)
COMMON/BL41/VFHSBW(5,8,34,34),VFHSBE(5,8,34,34),VFHSBS(5,8,34,34),
& VFHSBN(5,8,34,34),VFHSBB(5,8,34,34),VFHSBF(5,8,34,34)
COMMON/BL43/QSCONF,QSCONB,QSCONE,QSCONW,QSCONN,QSCONS,QRADF,
& QRADB,QRADAE,QRADW,QRADN,QRADS,WAIR,WWAL,WINS,
& WERR,WWFAN
DATA SORMAX,XTIME,ITMAX/3.00,0.0,4/

```

```

C ***** INITIAL PROGRAM START *****
CALL CPUTIME(BEGIN,IPR)

```

```

C *** INPUT DATA
CALL INPUT(NSTOP)
IF(NSTOP.GT.0) GOTO 9999

```

```

C *** GENERATE GRID SYSTEM
CALL GRID

```

```

C *** INITIALIZE THE ALL DATA FIELDS
CALL INIT

```

```

C *** OPEN OUTPUT FILES
OPEN(12,FILE='/OUTPUT DATA B1',STATUS='UNKNOWN')
OPEN(13,FILE='/PLOT DATA B4',STATUS='UNKNOWN',
& FORM='UNFORMATTED')

```

```

C *** CALCULATE THE VIEW FACTORS FROM THE FIRE TO THE WALLS
CALL VIEW

```

```

***** START CALCULATIONS *****

```

```

NT=0
NTIM=0
300 NT=NT+1

```

```

C *** ON RESTART NTMAX0 IS SET EQUAL TO OLD VALUE FOR NTREAL
IF(TIME.GE.TMAX) GO TO 277
NTREAL=NT+NTMAX0
TIME=TIME+DTIME

```

```

XTIME=TIME*H/U0
C      PRINT 3,'CURRENT FIRE TIME IS:',XTIME,'SECONDS'
C      3 FORMAT (1X,A,1X,F10.6,1X,A)

C **** CALCULATE THE HEAT SOURCE IN BTU/SEC
      CALL CALQ

C **** START CALCULATIONS
      ITER=0
      JTERM=0
      JJTERM=0

C **** PREDICT VARIABLE FIELDS FOR USE BY CALVIS AND SU(I,J,K)
      DO 48 K=1,NK+4
      DO 48 J=1,NJ+4
      DO 48 I=1,NI+4
         TPD(I,J,K)=T(I,J,K)
         CPD(I,J,K)=C(I,J,K)
         RPD(I,J,K)=R(I,J,K)
         UPD(I,J,K)=U(I,J,K)
         VPD(I,J,K)=V(I,J,K)
         WPD(I,J,K)=W(I,J,K)
48   CONTINUE
47   JTERM=JTERM+1
301  NTITER=0
312  NTITER=NTITER+1

C **** IF FIRE HAS STARTED, CALCULATE THE TEMPERATURE
      IF (XTIME.GE.HSTART) CALL CALT

*****THIS STEP CAN BE SKIPPED WHEN COMPARTMENT IS OPEN TO OUTSIDE*****
C *** CORRECT GLOBAL PRESSURE FOR TOTAL MASS CONSERVATION
      CALL GLOBE

C *** CALCULATE DENSITY
      DO 100 J=1,NJ+4
      DO 100 I=1,NI+4
      DO 100 K=1,NK+4
         IF (NOD(I,J,K).EQ.1) GOTO 100
         AAAA=BUOY*UGRT*HEIGHT(I,J,K)
         R(I,J,K)=(UGRT*P(I,J,K)+(1./EXP(AAAA)))/T(I,J,K)
100   CONTINUE

*****THIS STEP CAN BE SKIPPED WHEN COMPARTMENT IS OPEN TO OUTSIDE*****
C *** ITERATE INSIDE TEMPERATURE LOOP TO ASSURE GLOBAL CONSERVATION
C *** OF MASS AND ENERGY
      IF (NTITER.LT.2) GOTO 312

C *** PRINT OUT THE ENERGY DISTRIBUTION
*      IF (MOD(NTREAL,NWRP).EQ.0) CALL OUT(4)

C *** CALCULATE THE SMOKE CONCENTRATION
      CALL CALC

C *** CALCULATE TURBULENT VISCOSITY AND CONDUCTIVITY
      CALL CALVIS

```

```

C **** CORRECT CONDUCTIVITY OF THE SOLID
IF (NCHIP.NE.0) CALL SOLCON

C **** START PRESSURE CORRECTION ITERATIVE LOOP
C **** IT IS THE MAJOR PART OF THE ERROR CONTROL ROUTINE
ITER=ITER+1

C **** CALCULATE THE STRESS AND VELOCITY COMPONENTS U,V,AND W
CALL STRESS
CALL CALU
CALL CALV
CALL CALW

C **** CALCULATE PRESSURE
CALL CALP

C **** IF SOURCE TERM IS LARGER THAN 10.0, STOP PROGRAM
IF (RESORM(ITER).GT.10.0) GOTO 2020

IF(RESORM(ITER).LE.SORMAX) GO TO 49
IF(ITER.EQ.1) GO TO 302
IF(RESORM(ITER) .LE. RESORM(ITER-1)) GO TO 302
GO TO 304

302 IF(JTERM .LT. 2) THEN
  SOURCE=RESORM(ITER)
ELSEIF(RESORM(ITER).LE.SOURCE) THEN
  SOURCE=RESORM(ITER)
ELSE
  GOTO 304
ENDIF
DO 23 K=1,NK+4
DO 23 J=1,NJ+4
DO 23 I=1,NI+4
  TPD(I,J,K)=T(I,J,K)
  CPD(I,J,K)=C(I,J,K)
  RPD(I,J,K)=R(I,J,K)
  UPD(I,J,K)=U(I,J,K)
  VPD(I,J,K)=V(I,J,K)
  WPD(I,J,K)=W(I,J,K)
  PPD(I,J,K)=P(I,J,K)
23 CONTINUE

JJTERM=0
IF(ITER.EQ.1TMAX) GO TO 49
IF(JTERM.EQ.2) GO TO 35
IF(ITER.EQ.4) GO TO 47
35 IF(JTERM.EQ.3) GO TO 58
IF(ITER.EQ.7) GO TO 47
58 JJTERM=0
GO TO 301
304 JJTERM=JJTERM+1
IF(JTERM.EQ.1) GOTO 41
IF(JTERM.EQ.2.AND.JJTERM.EQ.1.AND.ITER.NE.5) GO TO 41
GO TO 82

```

```

41 DO 40 K=1,NK+4
    DO 40 J=1,NJ+4
    DO 40 I=1,NI+4
        R(I,J,K)=RPD(I,J,K)
        U(I,J,K)=UPD(I,J,K)
        V(I,J,K)=VPD(I,J,K)
        W(I,J,K)=WPD(I,J,K)
        P(I,J,K)=PPD(I,J,K)
40 CONTINUE
    IF(ITER.EQ.ITMAX) GO TO 49
    GO TO 47

82 DO 43 K=1,NK+4
    DO 43 J=1,NJ+4
    DO 43 I=1,NI+4
        T(I,J,K)=TPD(I,J,K)
        C(I,J,K)=CPD(I,J,K)
        R(I,J,K)=RPD(I,J,K)
        U(I,J,K)=UPD(I,J,K)
        V(I,J,K)=VPD(I,J,K)
        W(I,J,K)=WPD(I,J,K)
        P(I,J,K)=PPD(I,J,K)
43 CONTINUE

    IF(ITER.EQ.ITMAX) GO TO 49
    IF((JTERM.EQ.3.AND.ITER.NE.8).OR.JJTERM.EQ.2) GO TO 49
    GO TO 301

49 ITERT=ITERT+ITER
*     IF (MOD(NTREAL,NWRP).EQ.0) CALL OUT(1)

C *** FIND TEMPERATURES AT THERMOCOUPLES AND PRINT OUT AT PROPER TIME
    CALL TCP
    IF (MOD(NTREAL,NWRITE).EQ.0) CALL OUT(2)

C *** OUTPUT FILED VALUES
    IF (MOD(NTREAL,NWRITE).EQ.0) CALL OUT(3)
    IF(TIME.GE.TMAX) GO TO 277

C *** SHIFT CURRENT TIME VALUES TO PREVIOUS TIME VALUES AND
C *** LOOP BACK FOR NEXT ITERATION
    DO 305 K=1,NK+4
    DO 305 J=1,NJ+4
    DO 305 I=1,NI+4
        TOD(I,J,K)=T(I,J,K)
        COD(I,J,K)=C(I,J,K)
        ROD(I,J,K)=R(I,J,K)
        UOD(I,J,K)=U(I,J,K)
        VOD(I,J,K)=V(I,J,K)
        WOD(I,J,K)=W(I,J,K)
        POD(I,J,K)=P(I,J,K)
305 CONTINUE

C *** OUTPUT TO DATA FILE FOR PLOTTING
    IF(MOD(NTREAL,NTAPE).EQ.0) THEN
        WRITE(13) TIME,T,U,V,W

```

```

ENDIF

C *** OUTPUT TO CONTINUATION FILE FOR RESTART
IF(MOD(NTREAL,100).EQ.0) THEN
    WRITE(11) TIME,NTREAL,FR,T,R,U,V,W,P,C
    REWIND 11
ENDIF
GO TO 300

C *** OUTPUT TO CONTINUATION FILE
277 WRITE(11) TIME,NTREAL,FR,T,R,U,V,W,P,C
GO TO 9999

2020 WRITE(12,*)'RESIDUAL MASS IS LARGER THAN 10.0',
&                  ' PROGRAM STOPS AT TIME = ',XTIME,' SEC'

9999 CALL CPUTIME(END,IPR)
    WRITE (12,*) 'CPU RUN TIME = ',(END-BEGIN)*1.E-6,' SECONDS'
    STOP
END

*****
***** BLOCK DATA *****
*****
* U0      : REFERENCE VELOCITY = 1.0 FT/SEC
* PRT     : TURBULENT PRANDTL NUMBER = 1.0
* RHOO    : REFERENCE DENSITY OF AIR = 0.0714 LBM/FT**3
* CPO     : REFERENCE SPECIFIC HEAT OF AIR = 0.24 BTU/(LBM*F)
* VISO    : REFERENCE VISCOSITY = 1.56E-4
* CNT     :
* ABTURB  : TURBULENCE CONSTANT
* BTURB   : TURBULENCE CONSTANT
* GC      : GRAVITATIONAL ACCELERATION = 32.17 FT/SEC**2
* RAIR    : GAS CONSTANT FOR AIR = 53.34
* ALEW    : LEWIS NUMBER = 1.0
***** IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/BL12/NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER
COMMON/BL14/HCOEF,CNT,ABTURB,BTURB,VISL,VISMAX
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,CONDO,VISO,RHOO,
&          TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL39/ALEW,CONSRA,QSIN,QSWER,QSWAL,QSAIR,QSFAN

C *** SPECIFY THE INITIAL DATA
DATA U0, PRT, RHOO, CPO, VISO, NTMAX0/
& 1.0, 1.0, 0.0714, 0.24, 1.56D-4, 0/
DATA CNT,ABTURB,BTURB/0.2,2.0,1.0/
DATA GC,RAIR,ALEW/32.17,53.34,1.0/
END

*****
*****
```

SUBROUTINE CALC

\*\*\*\*\*  
\*THIS SUBROUTINE CALCULATES THE SMOKE CONCENTRATIONS

IMPLICIT DOUBLE PRECISION (A-H,O-Z)  
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),  
& DYYC(40),DZZC(40),DXXS(40),DYYYS(40),DZZS(40)  
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR  
COMMON/BL2/X,Y,H,TFLR,TWAL  
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP  
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),  
& COD(25,25,15),UOD(25,25,15),VOD(25,25,15),  
& WOD(25,25,15)  
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),  
& U(25,25,15),V(25,25,15),W(25,25,15)  
COMMON/BL33/TPD(25,25,15),RPD(25,25,15),PPD(25,25,15),  
& CPD(25,25,15),UPD(25,25,15),VPD(25,25,15),  
& WPD(25,25,15)  
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),  
& AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),  
& SU(25,25,15),RI(25,25,15)  
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),  
& CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)  
COMMON/BL39/ALEW,CONSRA,QSIN,QSWER,QSWAL,QSAIR,QSFAN

C \*\*\* CALCULATE COEFFICIENTS

DO 100 K=2,NK+3  
DO 100 J=2,NJ+3  
DO 100 I=2,NI+3

C \*\*\* CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME

DXP1=DXXC(I+1)  
DXI =DXXC(I)  
DXM1=DXXC(I-1)

DYP1=DYYC(J+1)  
DYJ =DYYC(J)  
DYM1=DYYC(J-1)

DZP1=DZZC(K+1)  
DZK =DZZC(K)  
DZM1=DZZC(K-1)

C \*\*\* SURFACE LENGTH OF THE CONTROL VOLUME

DXN=DXXC(I)  
DXS=DXXC(I)  
DXF=DXXC(I)  
DXB=DXXC(I)

DYF=DYYC(J)  
DYB=DYYC(J)  
DYE=DYYC(J)  
DYW=DYYC(J)

DZE=DZZC(K)  
DZW=DZZC(K)

```

DZN=DZZC(K)
DZS=DZZC(K)

C **** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T
DXEE=DXXS(I+2)
DXE =DXXS(I+1)
DXW =DXXS(I)
DXWW=DXXS(I-1)

DYNN=DYYS(J+2)
DYN =DYYS(J+1)
DYS =DYYS(J)
DYSS=DYYS(J-1)

DZFF=DZZS(K+2)
DZF =DZZS(K+1)
DZB =DZZS(K)
DZBB=DZZS(K-1)

C **** DEFINE THE AREA OF THE CONTROL VOLUME
DXYF=DXF*DYF
DXYB=DXB*DYB
DYZE=DYE*DZE
DYZW=DYW*DZW
DZXN=DZN*DXN
DZXS=DZS*DXS

VOL=DXI*DYJ*DZK
VOLDT=VOL/DTIME

ZXOYN=DZXN/DYN
ZXOYS=DZXS/DYS
XYOZF=DXYF/DZF
XYOZB=DXYB/DZB
YZOXE=DYZE/DXE
YZOXW=DYZW/DXW

C **** DENSITY AT THE SURFACES OF THE CONTROL VOLUME
GN=(R(I,J,K)*DYP1+R(I,J+1,K)*DYJ)/(DYP1+DYJ)
GS=(R(I,J,K)*DYM1+R(I,J-1,K)*DYJ)/(DYM1+DYJ)
GE=(R(I,J,K)*DXP1+R(I+1,J,K)*DXI)/(DXP1+DXI)
GW=(R(I,J,K)*DXM1+R(I-1,J,K)*DXI)/(DXM1+DXI)
GF=(R(I,J,K)*DZP1+R(I,J,K+1)*DZK)/(DZP1+DZK)
GB=(R(I,J,K)*DZM1+R(I,J,K-1)*DZK)/(DZM1+DZK)

CN=GN*V(I,J+1,K)*DZXN
CS=GS*V(I,J,K)*DZXS
CE=GE*U(I+1,J,K)*DYZE
CW=GW*U(I,J,K)*DYZW
CF=GF*W(I,J,K+1)*DXYF
CB=GB*W(I,J,K)*DXYB

C **** DIFFUSIVITY AT THE SURFACES OF THE CONTROL VOLUME
CONDN=(DYP1+DYJ)/(DYJ/COND(I,J,K)+DYP1/COND(I,J+1,K))
CONDJ=(DYM1+DYJ)/(DYJ/COND(I,J,K)+DYM1/COND(I,J-1,K))
CONDE=(DXP1+DXI)/(DXI/COND(I,J,K)+DXP1/COND(I+1,J,K))

```

```

CONDW=(DXM1+DXI)/(DXI/COND(I,J,K)+DXM1/COND(I-1,J ,K ))
CONDF=(DZP1+DZK)/(DZK/COND(I,J,K)+DZP1/COND(I ,J ,K+1))
CONDB=(DZM1+DZK)/(DZK/COND(I,J,K)+DZM1/COND(I ,J ,K-1))

```

```

CONDN1=ZXOYN*CONDN*ALEW
COND S1=ZXOYS*COND S*ALEW
CONDE1=YZOXE*CONDE*ALEW
CONDW1=YZOXW*CONDW*ALEW
COND F1=XYOZF*COND F*ALEW
COND B1=XYOZB*COND B*ALEW

```

C \*\*\*\* QUICK SCHEME

```

CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW ))/8.
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXEE))/8.
CWP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXWW))/8.
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DXE ))/8.

```

```

CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS ))/8.
CNM=(ABS(CN)-CN)*DYP1*DYJ/(DYN*(DYN+DYNN))/8.
CSP=(ABS(CS)+CS)*DYM1*DYJ/(DYS*(DYS+DYSS))/8.
CSM=(ABS(CS)-CS)*DYM1*DYJ/(DYS*(DYS+DYN ))/8.

```

```

CFP=(ABS(CF)+CF)*DZP1*DZK/(DZF*(DZF+DZB ))/8.
CFM=(ABS(CF)-CF)*DZP1*DZK/(DZF*(DZF+DZFF))/8.
CBP=(ABS(CB)+CB)*DZM1*DZK/(DZB*(DZB+DZBB))/8.
CBM=(ABS(CB)-CB)*DZM1*DZK/(DZB*(DZB+DZF ))/8.

```

```

AE(I,J,K)=-.5*CE*DXI/DXE+CEP+CEM*(1.+DXE/DXEE)+CWM*DXW/DXE
AW(I,J,K)= .5*CW*DXI/DXW+CWM+CWP*(1.+DXW/DXWW)+CEP*DXE/DXW
AN(I,J,K)=-.5*CN*DYJ/DYN+CNP+CNM*(1.+DYN/DYNN)+CSM*DYS/DYN
AS(I,J,K)= .5*CS*DYJ/DYS+CSM+CSP*(1.+DYS/DYSS)+CNP*DYN/DYS
AF(I,J,K)=-.5*CF*DZK/DZF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF
AB(I,J,K)= .5*CB*DZK/DZB+CBM+CBP*(1.+DZB/DZBB)+CFP*DZF/DZB

```

C \*\*\*\* BOUNDARY CONSIDERATION

```

IF (I.LT.NI+3) THEN
  AEE=-CEM*DXE/DXEE
  AEER=AEE*CPD(I+2,J,K)
ELSE
  AEE=0.
  AEER=0.
ENDIF

```

```

IF (I.GT.2) THEN
  AWW=-CWP*DXW/DXWW
  AWWR=AWW*CPD(I-2,J,K)
ELSE
  AWW=0.
  AWWR=0.
ENDIF

```

```

IF (J.LT.NJ+3) THEN
  ANN=-CNM*DYN/DYNN
  ANNR=ANN*CPD(I,J+2,K)
ELSE
  ANN=0.
ENDIF

```

```

      ANNR=0.
      ENDIF

      IF (J.GT.2) THEN
          ASS=-CSP*DYS/DYSS
          ASSR=ASS*CPD(I,J-2,K)
      ELSE
          ASS=0.
          ASSR=0.
      ENDIF

      IF (K.LT.NK+3) THEN
          AFF=-CFM*DZF/DZFF
          AFFR=AFF*CPD(I,J,K+2)
      ELSE
          AFF=0.
          AFFR=0.
      ENDIF

      IF (K.GT.2) THEN
          ABB=-CBP*DZB/DZBB
          ABBR=ABB*CPD(I,J,K-2)
      ELSE
          ABB=0.
          ABBR=0.
      ENDIF

C *** MODIFICATION FOR DECK BOUNDARIES
      IF (NOD(I-1,J,K).NE.0) THEN
          AWW=0.0
          AWWR=0.0
      ENDIF

      IF (NOD(I+1,J,K).NE.0) THEN
          AEE=0.0
          AEER=0.0
      ENDIF

      IF (NOD(I,J-1,K).NE.0) THEN
          ASS=0.0
          ASSR=0.0
      ENDIF

      IF (NOD(I,J+1,K).NE.0) THEN
          ANN=0.0
          ANNR=0.0
      ENDIF

      IF (NOD(I,J,K-1).NE.0) THEN
          ABB=0.0
          ABBR=0.0
      ENDIF

      IF (NOD(I,J,K+1).NE.0) THEN
          AFF=0.0
          AFFR=0.0

```

```

ENDIF

&          AP(I,J,K)=AE(I,J,K)+AW(I,J,K)+AN(I,J,K)+AS(I,J,K)+AF(I,J,K)+  

&          AB(I,J,K)+AEE+AWW+ANN+ASS+AFF+ABB+CONDE1+CONDW1+  

&          CONDN1+CONDNS1+CONDFF1+CONDDB1

AE(I,J,K)=AE(I,J,K)+CONDE1
AW(I,J,K)=AW(I,J,K)+CONDW1
AN(I,J,K)=AN(I,J,K)+CONDN1
AS(I,J,K)=AS(I,J,K)+CONDNS1
AF(I,J,K)=AF(I,J,K)+CONDFF1
AB(I,J,K)=AB(I,J,K)+CONDDB1

SP(I,J,K)=-ROD(I,J,K)*VOLDT
SU(I,J,K)=-SP(I,J,K)*COD(I,J,K)+AEER+AWWR+ANNR+ASSR+AFFR+ABBR
100 CONTINUE

C *** TAKE CARE OF B.C. THRU AN,AS,AE,AW,AF,AB,SP AND SU

C *** Y DIRECTION
DO 500 I=2,NI+3
DO 500 K=2,NK+3
  SP(I,3      ,K)=SP(I,3      ,K)+AS(I,3      ,K)
  SP(I,NJ+2,K)=SP(I,NJ+2,K)+AN(I,NJ+2,K)
  AS(I,3      ,K)=0.
  AN(I,NJ+2,K)=0.
500 CONTINUE

C *** X DIRECTION
DO 600 J=2,NJ+3
DO 600 K=2,NK+3
  SP(3      ,J,K)=SP(3      ,J,K)+AW(3      ,J,K)
  SP(NI+2,J,K)=SP(NI+2,J,K)+AE(NI+2,J,K)
  AW(3      ,J,K)=0.0
  AE(NI+2,J,K)=0.0
600 CONTINUE

C *** Z DIRECTION
DO 700 I=2,NI+3
DO 700 J=2,NJ+3
  SP(I,J,3      )=SP(I,J,3      )+AB(I,J,3      )
  SP(I,J,NK+2)=SP(I,J,NK+2)+AF(I,J,NK+2)
  AB(I,J,3      )=0.
  AF(I,J,NK+2)=0.
700 CONTINUE

C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS
DO 300 K=2,NK+3
DO 300 J=2,NJ+3
DO 300 I=2,NI+3
  AP(I,J,K)=AP(I,J,K)-SP(I,J,K)
300 CONTINUE

C *** VOLUMETRIC MASS SOURCE INPUT
VOLT=0.0
DO 113 I=2,NI+3

```

```

DO 113 J=2,NJ+3
DO 113 K=2,NK+3
  DXI =DXXC(I)
  DYJ =DYYC(J)
  DZK =DZZC(K)
  VOL =DXI*DYJ*DZK*H**3
  VOLT=VOLT+VOL
113 CONTINUE

DO 111 I=NHSZ(1,1),NHSZ(1,2)
DO 111 J=NHSZ(2,1),NHSZ(2,2)
DO 111 K=NHSZ(3,1),NHSZ(3,2)
  DXI =DXXC(I)
  DYJ =DYYC(J)
  DZK =DZZC(K)
  VOL =DXI*DYJ*DZK
  SU(I,J,K)=SU(I,J,K)+VOL*H/(U0*RHO0*VOLT)
111 CONTINUE

C **** SOLVE FOR C
  CALL TRID (3,3,3,NI+2,NJ+2,NK+2,C)

C **** Z DIRECTION
  DO 74 I=1,NI+4
  DO 74 J=1,NJ+4
    C(I,J,2)=C(I,J,3)
    C(I,J,1)=C(I,J,2)
    C(I,J,NK+3)=C(I,J,NK+2)
    C(I,J,NK+4)=C(I,J,NK+3)
74 CONTINUE

C **** Y DIRECTION
  DO 84 I=2,NI+3
  DO 84 K=2,NK+3
    C(I,NJ+3,K)=C(I,NJ+4,K)
    C(I,NJ+4,K)=C(I,NJ+3,K)
    C(I,2,K)=C(I,3,K)
    C(I,1,K)=C(I,2,K)
84 CONTINUE

C **** X DIRECTION
  DO 80 J=1,NJ+4
  DO 80 K=1,NK+4
    C(2,J,K)=C(3,J,K)
    C(1,J,K)=C(2,J,K)
    C(NI+3,J,K)=C(NI+2,J,K)
    C(NI+4,J,K)=C(NI+3,J,K)
80 CONTINUE

  RETURN
END

```

\*\*\*\*\*  
\*\*\*\*\*

## SUBROUTINE CALP

\*\*\*\*\*  
\*CALCULATES NODE PRESSURES

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
& DYYC(40),DZZC(40),DXXS(40),DYYs(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL12/NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
& JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL23/RMS(20),NMS,IMSB(20),NMSI(20),JMSB(20),NMSJ(20),
& KMSB(20),NMSK(20)
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),
& COD(25,25,15),UOD(25,25,15),VOD(25,25,15),
& WOD(25,25,15)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
& U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
& SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
& DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
& AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
& SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
& CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)

C **** CALCULATE COEFFICIENTS
DO 100 K=2,NK+3
DO 100 J=2,NJ+3
DO 100 I=2,NI+3

IF (NOD(I,J,K).EQ.1) GOTO 100

C **** CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME
DXP1=DXXC(I+1)
DXI =DXXC(I)
DXM1=DXXC(I-1)

DYP1=DYYC(J+1)
DYJ =DYYC(J)
DYM1=DYYC(J-1)

DZP1=DZZC(K+1)
DZK =DZZC(K)
DZM1=DZZC(K-1)

C **** SURFACE LENGTH OF THE CONTROL VOLUME
DXN=DXXC(I)
DXS=DXXC(I)
DXF=DXXC(I)
DXB=DXXC(I)

DYF=DYYC(J)
DYB=DYYC(J)

```

```

DYE=DYYC(J)
DYW=DYYC(J)

DZE=DZZC(K)
DZW=DZZC(K)
DZN=DZZC(K)
DZS=DZZC(K)

C **** DEFINE AREA OF THE CONTROL VOLUME
DXYF=DXF*DYF
DXYB=DXB*DYB
DYZE=DYE*DZE
DYZW=DYW*DZW
DZXN=DZN*DXN
DZXS=DZS*DXS

VOL=DXI*DYJ*DZK
VOLDT=VOL/DTIME

C **** DENSITY AT THE SURFACES
RN=(R(I,J,K)*DYP1+R(I,J+1,K)*DYJ)/(DYP1+DYJ)
RS=(R(I,J,K)*DYM1+R(I,J-1,K)*DYJ)/(DYM1+DYJ)
RE=(R(I,J,K)*DXP1+R(I+1,J,K)*DXI)/(DXP1+DXI)
RW=(R(I,J,K)*DXM1+R(I-1,J,K)*DXI)/(DXM1+DXI)
RF=(R(I,J,K)*DZP1+R(I,J,K+1)*DZK)/(DZP1+DZK)
RB=(R(I,J,K)*DZM1+R(I,J,K-1)*DZK)/(DZM1+DZK)

AN(I,J,K)=RN*DZXN*DV(I,J+1,K)
AS(I,J,K)=RS*DZXS*DV(I,J,K)
AE(I,J,K)=RE*DYZE*DU(I+1,J,K)
AW(I,J,K)=RW*DYZW*DU(I,J,K)
AF(I,J,K)=RF*DXYF*DW(I,J,K+1)
AB(I,J,K)=RB*DXYB*DW(I,J,K)

CN=RN*V(I,J+1,K)*DZXN
CS=RS*V(I,J,K)*DZXS
CE=RE*U(I+1,J,K)*DYZE
CW=RW*U(I,J,K)*DYZW
CF=RF*W(I,J,K+1)*DXYF
CB=RB*W(I,J,K)*DXYB

SMP(I,J,K)=-(R(I,J,K)-ROD(I,J,K))*VOLDT-CE+CW-CN+CS-CF+CB
SU(I,J,K)= SMP(I,J,K)
SP(I,J,K)= 0.

100 CONTINUE

C **** CONSIDER THE MASS SOURCE INPUT INTO THE CONTROL VOLUME
IF (NMS.GE.1) THEN
  DO 150 M=1,NMS
    IB=IMSB(M)
    IE=IB+NMSI(M)-1
    JB=JMSB(M)
    JE=JB+NMSJ(M)-1
    KB=KMSB(M)
    KE=KB+NMSK(M)-1
    DO 160 I=IB,IE-1

```

```

        DO 160 J=JB,JE-1
        DO 160 K=KB,KE-1
          SU(I,J,K)=SU(I,J,K)+RMS(M)
160      CONTINUE
150      CONTINUE
      ENDIF

C **** TAKE CARE OF B.C. THRU AN,AS,AE,AW,AF,AB,SP AND SU

C **** X DIRECTION
  DO 500 K=2,NK+3
  DO 500 I=2,NI+3
    AS(I,2      ,K)=0.
    AN(I,NJ+3,K)=0.
500  CONTINUE

C **** Y DIRECTION
  DO 501 K=2,NK+3
  DO 501 J=2,NJ+3
    AW(2      ,J,K)=0.
    AE(NI+3,J,K)=0.
501  CONTINUE

C **** Z -DIRECTION
  DO 502 I=2,NI+3
  DO 502 J=2,NJ+3
    AB(I,J,2      )=0.
    AF(I,J,NK+3)=0.
502  CONTINUE

C **** MODIFICATION FOR DECK BOUNDARIES
  IF (NCHIP.EQ.0) GOTO 110
  DO 101 N=1,NCHIP
    IB   =ICHPB(N)
    IE   =IB+NCHPI(N)-1
    JB   =JCHPB(N)
    JE   =JB+NCHPJ(N)-1
    KB   =KCHPB(N)
    KE   =KB+NCHPK(N)-1

    DO 102 J=JB,JE-1
    DO 102 K=KB,KE-1
      AE(IB-1,J,K)=0.0
      AW(IE      ,J,K)=0.0
102    CONTINUE

    DO 103 I=IB,IE-1
    DO 103 K=KB,KE-1
      AN(I,JB-1,K)=0.0
      AS(I,JE      ,K)=0.0
103    CONTINUE

    DO 106 I=IB,IE-1
    DO 106 J=JB,JE-1
      AF(I,J,KB-1)=0.0
      AB(I,J,KE      )=0.0

```

106 CONTINUE

C \*\*\* FOR THE CELLS INSIDE OF THE DECKS

```
DO 104 I=IB,IE-1
DO 104 J=JB,JE-1
DO 104 K=KB,KE-1
  SP(I,J,K)=-1.0E2
  AW(I,J,K)=0.
  AE(I,J,K)=0.
  AS(I,J,K)=0.
  AN(I,J,K)=0.
  AB(I,J,K)=0.
  AF(I,J,K)=0.
  SU(I,J,K)=0.
```

104 CONTINUE

101 CONTINUE

C \*\*\* ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS

```
110 DO 300 I=2,NI+3
DO 300 J=2,NJ+3
DO 300 K=2,NK+3
  AP(I,J,K)=AN(I,J,K)+AS(I,J,K)+AE(I,J,K)+AW(I,J,K)-SP(I,J,K)
  &           +AF(I,J,K)+AB(I,J,K)
300 CONTINUE
```

C \*\*\* SOLUTION OF FINITE DIFFERENCE EQUATION
CALL TRID (3,3,3,NI+2,NJ+2,NK+2,PP)

C \*\*\* CORRECTION FOR VELOCITY U

```
DO 600 I=3,NI+3
DO 600 J=2,NJ+3
DO 600 K=2,NK+3
  U(I,J,K)=U(I,J,K)+DU(I,J,K)*(PP(I-1,J,K)-PP(I,J,K))
600 CONTINUE
```

C \*\*\* CORRECTION FOR VELOCITY V

```
DO 603 J=3,NJ+3
DO 603 K=2,NK+3
DO 603 I=2,NI+3
  V(I,J,K)=V(I,J,K)+DV(I,J,K)*(PP(I,J-1,K)-PP(I,J,K))
603 CONTINUE
```

C \*\*\* CORRECTION FOR VELOCITY W

```
DO 604 K=3,NK+3
DO 604 I=2,NI+3
DO 604 J=2,NJ+3
  W(I,J,K)=W(I,J,K)+DW(I,J,K)*(PP(I,J,K-1)-PP(I,J,K))
604 CONTINUE
```

C \*\*\* CORRECTION FOR PRESSURE P

```
DO 606 J=1,NJ+4
DO 606 I=1,NI+4
DO 606 K=1,NK+4
  P(I,J,K)=P(I,J,K)+PP(I,J,K)
  PP(I,J,K)=0.
606 CONTINUE
```

```

C *** RESET THE VELOCITY INSIDE OF DECK
IF (NCHIP.EQ.0) GOTO 121
DO 120 N=1,NCHIP
  IB=ICHPB(N)
  IE=IB+NCHPI(N)-1
  JB=JCHPB(N)
  JE=JB+NCHPJ(N)-1
  KB=KCHPB(N)
  KE=KB+NCHPK(N)-1
  DO 109 I=IB,IE
  DO 109 J=JB,JE-1
  DO 109 K=KB,KE-1
    U(I,J,K)=0.0
109    CONTINUE

  DO 118 I=IB,IE-1
  DO 118 J=JB,JE
  DO 118 K=KB,KE-1
    V(I,J,K)=0.0
118    CONTINUE

  DO 119 I=IB,IE-1
  DO 119 J=JB,JE-1
  DO 119 K=KB,KE
    W(I,J,K)=WFAN(N)
119    CONTINUE
120    CONTINUE

C *** RECALCULATE THE ERROR SOURCE AFTER CORRECTIONS OF U, V, P
121    SORSUM=0.
      RESORM(ITER)=0.
      DO 700 J=2,NJ+3
      DO 700 I=2,NI+3
      DO 700 K=2,NK+3
        IF (NOD(I,J,K).NE.1) THEN

C *** CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME
      DXP1=DXXC(I+1)
      DXI =DXXC(I)
      DXM1=DXXC(I-1)

      DYP1=DYYC(J+1)
      DYJ =DYYC(J)
      DYM1=DYYC(J-1)

      DZP1=DZZC(K+1)
      DZK =DZZC(K)
      DZM1=DZZC(K-1)

C *** SURFACE LENGTH OF THE CONTROL VOLUME
      DXN=DXXC(I)
      DXS=DXXC(I)
      DXF=DXXC(I)
      DXB=DXXC(I)

```

```

DYF=DYYC(J)
DYB=DYYC(J)
DYE=DYYC(J)
DYW=DYYC(J)

DZE=DZZC(K)
DZW=DZZC(K)
DZN=DZZC(K)
DZS=DZZC(K)

C **** DEFINE AREA OF THE CONTROL VOLUME
DXYF=DXF*DYF
DXYB=DXB*DYB
DYZE=DYE*DZE
DYZW=DYW*DZW
DZXN=DZN*DXN
DZXS=DZS*DXS

VOL=DXI*DYJ*DZK
VOLDT=VOL/DTIME

C **** CALCULATE DENSITY
RN=(R(I,J,K)*DYP1+R(I,J+1,K)*DYJ)/(DYP1+DYJ)
RS=(R(I,J,K)*DYM1+R(I,J-1,K)*DYJ)/(DYM1+DYJ)
RE=(R(I,J,K)*DXP1+R(I+1,J,K)*DXI)/(DXP1+DXI)
RW=(R(I,J,K)*DXM1+R(I-1,J,K)*DXI)/(DXM1+DXI)
RF=(R(I,J,K)*DZP1+R(I,J,K+1)*DZK)/(DZP1+DZK)
RB=(R(I,J,K)*DZM1+R(I,J,K-1)*DZK)/(DZM1+DZK)

CN=RN*V(I,J+1,K)*DZXN
CS=RS*V(I,J,K)*DZXS
CE=RE*U(I+1,J,K)*DYZE
CW=RW*U(I,J,K)*DYZW
CF=RF*W(I,J,K+1)*DXYF
CB=RB*W(I,J,K)*DXYB
SMP(I,J,K)=(ROD(I,J,K)-R(I,J,K))*VOLDT-CE+CW-CN+CS-CF+CB

C **** SORSUM IS ACTUAL MASS INCREASE OR DECREASE FROM CONTINUITY
C **** EQUATION, THIS WILL BE COMPARED TO MASS SOURCE

C **** CONSIDER THE MASS SOURCE INPUT INTO THE CONTROL VOLUME
IF (NMS.GT.0) THEN
  DO 250 M=1,NMS
    IB=IMSB(M)
    IE=IB+NMSI(M)-1
    JB=JMSB(M)
    JE=JB+NMSJ(M)-1
    KB=KMSB(M)
    KE=KB+NMSK(M)-1
    DO 260 II=IB,IE-1
    DO 260 JJ=JB,JE-1
    DO 260 KK=KB,KE-1
      IF ((II.EQ.I).AND.(JJ.EQ.J).AND.(KK.EQ.K)) THEN
        SMP(I,J,K)=SMP(I,J,K)+RMS(M)
      ENDIF
    CONTINUE
  ENDIF
END

```

```
250      CONTINUE
        ENDIF
        SORSUM=SORSUM+SMP(I,J,K)
```

```
C **** RESORM IS SUM OF THE ABSOLUTE VALUE OF SMP(I,J,K)
      RESORM(ITER)=RESORM(ITER)+ABS(SMP(I,J,K))
      ENDIF
```

```
700 CONTINUE
      RETURN
      END
```

```
*****
*****
```

```
SUBROUTINE CALQ
```

```
*****
*****
```

```
*
```

```
*VARIABLES:
```

```
*  BR      = MAXIMUM BURN RATE (LBM/SEC)
*  F       = MAXIMUM FUEL AVAILABLE (LBM)
*  FR      = TOTAL FUEL REMAINING (LBM)
*  H       = REFERENCE LENGTH (FT)
*  HC      = HEAT OF COMBUSTION (BTU/LBM)
*  HSTART= FIRE START TIME (SECONDS)
*  Q       = TOTAL HEAT INPUT (BTU/SEC)
*  TIME   = NONDIMENSIONAL FIRE TIME
*  U0     = REFERENCE VELOCITY (FT/SEC)
*  XTIME  = FIRE TIME (SECONDS)
*
```

```
*****
*****
```

```
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL2/X,Y,H,TFLR,TWAL
COMMON/BL3/F,FR,HSTART
COMMON/BL12/NWRITE,NTAPE,NTMAXO,NTREAL,TIME,SORSUM,ITER
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,COND0,VISO,RHO0,
&           TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
```

```
XTIME=TIME*H/U0
HC=2600.0
BR= 0.01
```

```
C **** CALCULATE HEAT RELEASE RATE (Q) IN BTU/SEC
C **** NOTE: THESE ALGORITHMS ASSUME A LINEAR INCREASE IN BOTH
C ***      HEAT RELEASE AND FUEL CONSUMPTION OVER THE FIRST
C ***      TWO SECONDS OF FIRE TIME, AFTER WHICH BOTH ARE AT
C ***      MAXIMUM
```

```
IF(XTIME.LT.HSTART) THEN
  Q=0.0
  FR=F
ELSEIF(XTIME.GE.HSTART.AND.(XTIME-HSTART).LE.2.0) THEN
  IF(FR.LE.0.0) THEN
    Q =0.0
    FR=0.0
  ELSE
```

```

        Q =HC*BR*(XTIME-HSTART)/2.
        FR=F-BR*(XTIME-HSTART)**2/2.
    ENDIF
ELSEIF((XTIME-HSTART).GT.2.0) THEN
    IF(FR.LE.0.0) THEN
        Q =0.0
        FR=0.0
    ELSE
        Q =HC*BR
        FR=F-BR*(XTIME-HSTART)
    ENDIF
ENDIF

C *** TAKE RADIATION HEAT FLUX INTO ACCOUNT
Q=Q-QR
IF (Q.LE.0.0) Q=0.

RETURN
END

```

```
*****
***** SUBROUTINE CALT *****
*****
```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&          DYYC(40),DZZC(40),DXXS(40),DYYS(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL2/X,Y,H,TFLR,TWAL
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL14/HCOEF,CNT,ABTURB,BTURB,VISL,VISMAX
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,CONDO,VISO,RHO0,
&          TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL23/RMS(20),NMS,IMSB(20),NMSI(20),JMSB(20),NMSJ(20),
&          KMSB(20),NMSK(20)
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),
&          COD(25,25,15),UOD(25,25,15),VOD(25,25,15),
&          WOD(25,25,15)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&          U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL33/TPD(25,25,15),RPD(25,25,15),PPD(25,25,15),
&          CPD(25,25,15),UPD(25,25,15),VPD(25,25,15),
&          WPD(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
&          SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
&          DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
&          AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
&          SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&          CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)
COMMON/BL39/ALEW,CONSRA,QSIN,QSWER,QSWAL,QSAIR,QSFAN
COMMON/BL43/QSCONF,QSCONF,QSCONB,QSCONE,QSCONW,QSCONN,QSCONS,
&          QSRADF,QSRADB,QSRADE,QSRADW,QSRADN,QSRADS,
&          WAIR,WWAL,WINS,WERR,WWFAN

```

```

C **** NONDIMENSIONAL REFERENCE TEMPERATURE
TINF=TA/TA

C **** CALCULATE COEFFICIENTS
DO 100 K=2,NK+3
DO 100 J=2,NJ+3
DO 100 I=2,NI+3

C **** CENTRAL LENGTH OF THE TEMPERATURE CONTROL VOLUME
DXP1=DXXC(I+1)
DXI =DXXC(I)
DXM1=DXXC(I-1)

DYP1=DYYC(J+1)
DYJ =DYYC(J)
DYM1=DYYC(J-1)

DZP1=DZZC(K+1)
DZK =DZZC(K)
DZM1=DZZC(K-1)

C **** SURFACE LENGTH OF THE CONTROL VOLUME
DXN=DXXC(I)
DXS=DXXC(I)
DXF=DXXC(I)
DXB=DXXC(I)

DYF=DYYC(J)
DYB=DYYC(J)
DYE=DYYC(J)
DYW=DYYC(J)

DZE=DZZC(K)
DZW=DZZC(K)
DZN=DZZC(K)
DZS=DZZC(K)

C **** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR TEMPERATURE
DXEE=DXXS(I+2)
DXE =DXXS(I+1)
DXW =DXXS(I)
DXWW=DXXS(I-1)

DYNN=DYYS(J+2)
DYN =DYYS(J+1)
DYS =DYYS(J)
DYSS=DYYS(J-1)

DZFF=DZZS(K+2)
DZF =DZZS(K+1)
DZB =DZZS(K)
DZBB=DZZS(K-1)

C **** DEFINE THE AREA OF THE CONTROL VOLUME
DXYF=DXF*DYF

```

```
DXYB=DXB*DYB
DYZE=DYE*DZE
DYZW=DYW*DZW
DZXN=DZN*DXN
DZXS=DZS*DXS
```

```
VOL=DXI*DYJ*DZK
VOLDT=VOL/DTIME
```

```
C **** FOR CONDUCTION
ZXOYN=DZXN/DYN
ZXOYS=DZXS/DYS
XYOZF=DXYF/DZF
XYOZB=DXYB/DZB
YZOXE=DYZE/DXE
YZOXW=DYZW/DWX
```

```
C **** DENSITY AT THE SURFACES
```

```
GN=(R(I,J,K)*DYP1+R(I,J+1,K)*DYJ)/(DYP1+DYJ)
GS=(R(I,J,K)*DYM1+R(I,J-1,K)*DYJ)/(DYM1+DYJ)
GE=(R(I,J,K)*DXP1+R(I+1,J,K)*DXI)/(DXP1+DXI)
GW=(R(I,J,K)*DXM1+R(I-1,J,K)*DXI)/(DXM1+DXI)
GF=(R(I,J,K)*DZP1+R(I,J,K+1)*DZK)/(DZP1+DZK)
GB=(R(I,J,K)*DZM1+R(I,J,K-1)*DZK)/(DZM1+DZK)
```

```
C **** THE MASS FLUX RATE THROUGH THE SURFACES
```

```
CN=GN*V(I,J+1,K)*DZXN
CS=GS*V(I,J,K)*DZXS
CE=GE*U(I+1,J,K)*DYZE
CW=GW*U(I,J,K)*DYZW
CF=GF*W(I,J,K+1)*DXYF
CB=GB*W(I,J,K)*DXYB
```

```
C **** CONDUCTIVITY AT THE SURFACES
```

```
CONDN=(DYP1+DYJ)*COND(I,J,K)*COND(I,J+1,K)*DYJ*DYP1/
& (DYJ*COND(I,J,K)+DYP1*COND(I,J+1,K))
COND=(DYM1+DYJ)*COND(I,J,K)*COND(I,J-1,K)*DYJ*DYM1/
& (DYJ*COND(I,J,K)+DYM1*COND(I,J-1,K))
CONDE=(DXP1+DXI)*COND(I,J,K)*COND(I+1,J,K)*DXI*DXP1/
& (DXI*COND(I,J,K)+DXP1*COND(I+1,J,K))
CONDW=(DXM1+DXI)*COND(I,J,K)*COND(I-1,J,K)*DXI*DXM1/
& (DXI*COND(I,J,K)+DXM1*COND(I-1,J,K))
CONDF=(DZP1+DZK)*COND(I,J,K)*COND(I,J,K+1)*DZK*DZP1/
& (DZK*COND(I,J,K)+DZP1*COND(I,J,K+1))
CONDB=(DZM1+DZK)*COND(I,J,K)*COND(I,J,K-1)*DZK*DZM1/
& (DZK*COND(I,J,K)+DZM1*COND(I,J,K-1))
```

```
C **** CONDUCTION COMPONENT
CONDN1=ZXOYN*CONDN
COND1=ZXOYS*COND1
CONDE1=YZOXE*CONDE
CONDW1=YZOXW*CONDW
CONDF1=XYOZF*CONDF
CONDB1=XYOZB*CONDB
```

```
C **** QUICK SCHEME
```

```

CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW )*8.)
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXEE)*8.)
CWP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXWW)*8.)
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DYE )*8.)

CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS )*8.)
CNM=(ABS(CN)-CN)*DYP1*DYJ/(DYN*(DYN+DYNN)*8.)
CSP=(ABS(CS)+CS)*DYM1*DYJ/(DYS*(DYS+DYSS)*8.)
CSM=(ABS(CS)-CS)*DYM1*DYJ/(DYS*(DYS+DYN )*8.)

CFP=(ABS(CF)+CF)*DZP1*DZK/(DZF*(DZF+DZB )*8.)
CFM=(ABS(CF)-CF)*DZP1*DZK/(DZF*(DZF+DZFF)*8.)
CBP=(ABS(CB)+CB)*DZM1*DZK/(DZB*(DZB+DZBB)*8.)
CBM=(ABS(CB)-CB)*DZM1*DZK/(DZB*(DZB+DZF )*8.)

AE(I,J,K)=-.5*CE*DXI/DXE+CEP+CEM*(1.+DXE/DXEE)+CWM*DXW/DXE
AW(I,J,K)= .5*CW*DXI/DXW+CWM+CWP*(1.+DXW/DXWW)+CEP*DYE/DXW
AN(I,J,K)=-.5*CN*DYJ/DYN+CNP+CNM*(1.+DYN/DYNN)+CSM*DYS/DYN
AS(I,J,K)= .5*CS*DYJ/DYS+CSM+CSP*(1.+DYS/DYSS)+CNP*DYN/DYS
AF(I,J,K)=-.5*CF*DZK/DZF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF
AB(I,J,K)= .5*CB*DZK/DZB+CBM+CBP*(1.+DZB/DZBB)+CFP*DZF/DZB

C **** BOUNDARY CONSIDERATIONS
  IF (I.LT.NI+3) THEN
    AEE=-CEM*DYE/DXEE
    AEER=AEE*TPD(I+2,J,K)*CPM(I+2,J,K)
  ELSE
    AEE=0.
    AEER=0.
  ENDIF

  IF (I.GT.2) THEN
    AWW=-CWP*DXW/DXWW
    AWWR=AWW*TPD(I-2,J,K)*CPM(I-2,J,K)
  ELSE
    AWW=0.
    AWWR=0.
  ENDIF

  IF (J.LT.NJ+3) THEN
    ANN=-CNM*DYN/DYNN
    ANNR=ANN*TPD(I,J+2,K)*CPM(I,J+2,K)
  ELSE
    ANN=0.
    ANNR=0.
  ENDIF

  IF (J.GT.2) THEN
    ASS=-CSP*DYS/DYSS
    ASSR=ASS*TPD(I,J-2,K)*CPM(I,J-2,K)
  ELSE
    ASS=0.
    ASSR=0.
  ENDIF

  IF (K.LT.NK+3) THEN

```

```

        AFF=-CFM*DZF/DZFF
        AFFR=AFF*TPD(I,J,K+2)*CPM(I,J,K+2)
    ELSE
        AFF=0.
        AFFR=0.
    ENDIF

    IF (K.GT.2) THEN
        ABB=-CBP*DZB/DZBB
        ABBR=ABB*TPD(I,J,K-2)*CPM(I,J,K-2)
    ELSE
        ABB=0.
        ABBR=0.
    ENDIF

C **** MODIFICATION FOR DECK BOUNDARIES
    IF (NOD(I-1,J,K).NE.0) THEN
        AWW=0.0
        AWWR=0.0
    ENDIF

    IF (NOD(I+1,J,K).NE.0) THEN
        AEE=0.0
        AEER=0.0
    ENDIF

    IF (NOD(I,J-1,K).NE.0) THEN
        ASS=0.0
        ASSR=0.0
    ENDIF

    IF (NOD(I,J+1,K).NE.0) THEN
        ANN=0.0
        ANNR=0.0
    ENDIF

    IF (NOD(I,J,K-1).NE.0) THEN
        ABB=0.0
        ABBR=0.0
    ENDIF

    IF (NOD(I,J,K+1).NE.0) THEN
        AFF=0.0
        AFFR=0.0
    ENDIF

    AP(I,J,K)=(AE(I,J,K)+AW(I,J,K)+AN(I,J,K)+AS(I,J,K)+AF(I,J,K)+  

&           AB(I,J,K)+AEE+AWW+ANN+ASS+AFF+ABB)*CPM(I,J,K)+  

&           CONDE1+CONDW1+CONDN1+CONDSD1+CONDFF1+CONDDB1
    AE(I,J,K)=AE(I,J,K)*CPM(I+1,J,K)+CONDE1
    AW(I,J,K)=AW(I,J,K)*CPM(I-1,J,K)+CONDW1
    AN(I,J,K)=AN(I,J,K)*CPM(I,J+1,K)+CONDN1
    AS(I,J,K)=AS(I,J,K)*CPM(I,J-1,K)+CONDSD1
    AF(I,J,K)=AF(I,J,K)*CPM(I,J,K+1)+CONDFF1
    AB(I,J,K)=AB(I,J,K)*CPM(I,J,K-1)+CONDDB1

```

```

        SP(I,J,K)=-ROD(I,J,K)*VOLDT*CPM(I,J,K)
        SU(I,J,K)=-SP(I,J,K)*TOD(I,J,K)+AEER+AWWR+ANNR+ASSR+AFFR+ABBR
100  CONTINUE

C *** TAKE CARE OF B.C. THRU AN,AS,AE,AW,AF,AB,SP AND SU

C *** Y-DIRECTION
DO 500 I=3,NI+2
DO 500 K=3,NK+2
    SU(I,3      ,K)=SU(I,3      ,K)+AS(I,3      ,K)*T(I,2      ,K)
    SU(I,NJ+2,K)=SU(I,NJ+2,K)+AN(I,NJ+2,K)*T(I,NJ+3,K)
    AS(I,3      ,K)=0.
    AN(I,NJ+2,K)=0.
500  CONTINUE

C *** X-DIRECTION
DO 600 J=3,NJ+2
DO 600 K=3,NK+2
    SU(3      ,J,K)=SU(3      ,J,K)+AW(3      ,J,K)*T(2      ,J,K)
    SU(NI+2,J,K)=SU(NI+2,J,K)+AE(NI+2,J,K)*T(NI+3,J,K)
    AW(3      ,J,K)=0.0
    AE(NI+2,J,K)=0.0
600  CONTINUE

C *** Z-DIRECTION
DO 700 I=3,NI+2
DO 700 J=3,NJ+2
    SU(I,J,3      )=SU(I,J,3      )+AB(I,J,3      )*T(I,J,2      )
    SU(I,J,NK+2)=SU(I,J,NK+2)+AF(I,J,NK+2)*T(I,J,NK+3)
    AB(I,J,3      )=0.
    AF(I,J,NK+2)=0.
700  CONTINUE

C *** CONSIDER THE MASS SOURCE INPUT TO THE CONTROL VOLUME
IF (NMS.GE.1) THEN
    DO 150 M=1,NMS
        IB=IMSB(M)
        IE=IB+NMSI(M)-1
        JB=JMSB(M)
        JE=JB+NMSJ(M)-1
        KB=KMSB(M)
        KE=KB+NMSK(M)-1
        DO 160 I=IB,IE-1
        DO 160 J=JB,JE-1
        DO 160 K=KB,KE-1
            IF (RMS(M).GE.0.0) THEN
                RMSCPT=RMS(M)*1.0*CPM(I,J,K)
            ELSE
                RMSCPT=RMS(M)*T(I,J,K)*CPM(I,J,K)*R(I,J,K)
            ENDIF
160      CONTINUE
150      CONTINUE
        ENDIF

C *** CONSIDER THE RADIATION HEAT FLUX FROM THE FIRE TO THE BLOCK
        CALL RADHT (2)

```

```

C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS
  DO 300 K=3,NK+2
  DO 300 J=3,NJ+2
  DO 300 I=3,NI+2
    AP(I,J,K)=AP(I,J,K)-SP(I,J,K)
300 CONTINUE

C *** VOLUME HEAT SOURCE INPUT

C *** CALCULATE THE TOTAL VOLUME OCCUPIED BY HEAT SOURCE
C *** DISTRIBUTE ENERGY INTO EACH CONTROL VOLUME
C *** QQQ/H**3      DIMENSIONLESS HEAT SOURCE

  VOLT=0.0
  DO 113 I=NHSZ(1,1),NHSZ(1,2)
  DO 113 J=NHSZ(2,1),NHSZ(2,2)
  DO 113 K=NHSZ(3,1),NHSZ(3,2)
    QQQ=Q*H/(U0*CP0*RHO0*TA)
    VOL=DXXC(I)*DYYC(J)*DZZC(K)
    VOLT=VOLT+VOL*H**3
    SU(I,J,K)=SU(I,J,K)+VOL*QQQ/VOLT
113 CONTINUE

C *** SOLVE FOR T
  CALL TRID (3,3,3,NI+2,NJ+2,NK+2,T)

  DO 2001 I=1,NI+4
  DO 2001 J=1,NJ+4
  DO 2001 K=1,NK+4
    IF(T(I,J,K).LT.TCOOL) T(I,J,K)=TCOOL
2001 CONTINUE

C *** CALCULATE RADIATION HEAT TRANSFER

C *** HERE SU(I,J,K) IS USED TO STORE THE RADIATIVE HEAT FLUX
  DO 75 I=1,NI+4
  DO 75 J=1,NJ+4
  DO 75 K=1,NK+4
    SU(I,J,K)=0.
75 CONTINUE

C *** CONSIDER THE RADIATION HEAT FLUX FROM THE FIRE TO THE WALL
  CALL RADHT (1)

C *** SUMMATION OF CONDUCTION HEAT FLUX AND RADIATION HEAT FLUX TO WALLS
  QSCONF=0.
  QSCONB=0.
  QSCONE=0.
  QSCONW=0.
  QSCONN=0.
  QSCONS=0.

  QSRADF=0.
  QSRADB=0.
  QSRADE=0.

```

```
QSRADW=0.  
QSRADN=0.  
QSRADS=0.
```

```
C *** CALCULATE CONDUCTION, RADIATION & TEMPERATURE ON THE SOLID WALLS  
DO 74 I=3,NI+2  
DO 74 J=3,NJ+2
```

```
C *** ON THE BACK WALL
```

```
DZK =DZZC(2)  
DZP1=DZZC(3)  
DXI =DXXC(I)  
DYJ =DYYC(J)  
DXY =DXI*DYJ  
VOL =DXY*DZK  
COND=(DZP1+DZK)*DZK*DZP1*COND(I,J,2)*COND(I,J,3)/  
& (DZK*COND(I,J,2)+DZP1*COND(I,J,3))  
QCONF=DXY*COND*(T(I,J,3)-T(I,J,2))*2.0/(DZP1+DZK)  
QCONB=DXY*COND(I,J,2)*(T(I,J,1)-T(I,J,2))*2.0/DZK  
QRADB=SU(I,J,2)  
  
T(I,J,2)=TOD(I,J,2)+DTIME*(QCONF+QCONB+QRADB)/(VOL*CPM(I,J,2))  
T(I,J,1)=(2.*COND(I,J,2)*T(I,J,2)+HCOEF*TINF*DZK)/  
& (HCOEF*DZK+2.*COND(I,J,2))  
  
QSCONB=QSCONB+QCONF  
QSRADB=QSRADB+QRADB
```

```
C *** ON THE FRONT WALL
```

```
DZK =DZZC(NK+3)  
DZM1=DZZC(NK+2)  
DXI =DXXC(I)  
DYJ =DYYC(J)  
DXY =DXI*DYJ  
VOL =DXY*DZK  
COND=(DZM1+DZK)*DZK*DZM1*COND(I,J,NK+3)*COND(I,J,NK+2)/  
& (DZK*COND(I,J,NK+3)+DZM1*COND(I,J,NK+2))  
QCONB=DXY*COND*(T(I,J,NK+2)-T(I,J,NK+3))*2.0/(DZK+DZM1)  
QCONF=DXY*COND(I,J,NK+3)*(T(I,J,NK+4)-T(I,J,NK+3))*2.0/DZK  
QRADF=SU(I,J,NK+3)  
  
T(I,J,NK+3)=TOD(I,J,NK+3)+DTIME*(QCONB+QCONF+QRADF)/  
& (VOL*CPM(I,J,NK+3))  
T(I,J,NK+4)=(2.0*COND(I,J,NK+3)*T(I,J,NK+3)+HCOEF*TINF*DZK)/  
& (HCOEF*DZK+2.0*COND(I,J,NK+3))  
  
QSCONF=QSCONF+QCONB  
QSRADF=QSRADF+QRADF
```

```
74 CONTINUE
```

```
DO 84 I=3,NI+2  
DO 84 K=3,NK+2
```

```
C *** ON THE SOUTH WALL  
DYJ =DYYC(2)
```

```

DYP1=DYYC(3)
DXI =DXXC(I)
DZK =DZZC(K)
DZX =DZK*DXI
VOL =DZX*DYJ
CONDN=(DYP1+DYJ)*DYJ*DYP1*COND(I,2,K)*COND(I,3,K)/
& (DYJ*COND(I,2,K)+DYP1*COND(I,3,K))
QCONN=DZX*CONDN*(T(I,3,K)-T(I,2,K))*2.0/(DYP1+DYJ)
QCONS=DZX*COND(I,2,K)*(T(I,1,K)-T(I,2,K))*2.0/DYJ
QRADS=SU(I,2,K)
T(I,2,K)=TOD(I,2,K)+DTIME*(QCONN+QCONS+QRADS)/
& (VOL*CPM(I,2,K))
T(I,1,K)=(2.0*COND(I,2,K)*T(I,2,K)+HCOEF*TINF*DYJ)/
& (HCOEF*DYJ+2.0*COND(I,2,K))

QSCONS=QSCONS+QCONN
QSRADS=QSRADS+QRADS

C *** ON THE NORTH WALL
DYJ =DYYC(NJ+3)
DYM1=DYYC(NJ+2)
DXI =DXXC(I)
DZK =DZZC(K)
DZX =DZK*DXI
VOL =DZX*DYJ
COND=(DYM1+DYJ)*DYJ*DYM1*COND(I,NJ+3,K)*COND(I,NJ+2,K)/
& (DYJ*COND(I,NJ+3,K)+DYM1*COND(I,NJ+2,K))
QCONS=DZX*COND*(T(I,NJ+2,K)-T(I,NJ+3,K))*2.0/(DYM1+DYJ)
QCONN=DZX*COND(I,NJ+3,K)*(T(I,NJ+4,K)-T(I,NJ+3,K))*2.0/DYJ
QRADN=SU(I,NJ+3,K)
T(I,NJ+3,K)=TOD(I,NJ+3,K)+DTIME*(QCONS+QCONN+QRADN)/
& (VOL*CPM(I,NJ+3,K))
T(I,NJ+4,K)=(2.0*COND(I,NJ+3,K)*T(I,NJ+3,K)+HCOEF*TINF*DYJ)/
& (HCOEF*DYJ+2.0*COND(I,NJ+3,K))

QSCCONN=QSCCONN+QCONS
QSRADN=QSRADN+QRADN
84  CONTINUE

DO 80 J=3,NJ+2
DO 80 K=3,NK+2

C *** ON THE WEST WALL
DXI =DXXC(2)
DXP1=DXXC(3)
DYJ =DYYC(J)
DZK =DZZC(K)
DYZ =DYJ*DZK
VOL =DYZ*DXI
CONDE=(DXP1+DXI)*DXI*DXP1*COND(2,J,K)*COND(3,J,K)/
& (DXI*COND(2,J,K)+DXP1*COND(3,J,K))
QCONE=DYZ*CONDE *(T(3,J,K)-T(2,J,K))*2.0/(DXI+DXP1)
QCONW=DYZ*COND(2,J,K)*(T(1,J,K)-T(2,J,K))*2.0/DXI
QRADW=SU(2,J,K)
T(2,J,K)=TOD(2,J,K)+DTIME*(QCONE+QCONW+QRADW)/(VOL*CPM(2,J,K))
T(1,J,K)=(2.0*COND(2,J,K)*T(2,J,K)+HCOEF*TINF*DXI)/

```

& (HCOEF\*DXI+2.0\*COND(2,J,K))

QSCONW=QSCONW+QCONE  
QSRADW=QSRADW+QRADW

C \*\*\* ON THE EAST WALL

DXI =DXXC(NI+3)

DXM1=DXXC(NI+2)

DYJ =DYYC(J)

DZK =DZZC(K)

DYZ =DYJ\*DZK

VOL =DYZ\*DXI

CONDW=(DXM1+DXI)\*DXI\*DXM1\*COND(NI+3,J,K)\*COND(NI+2,J,K)/  
& (DXI\*COND(NI+3,J,K)+DXM1\*COND(NI+2,J,K))

QCONW=DYZ\*CONDW \*(T(NI+2,J,K)-T(NI+3,J,K))\*2.0/(DXI+DXM1)

QCONE=DYZ\*COND(2,J,K)\*(T(NI+4,J,K)-T(NI+3,J,K))\*2.0/DXI

QRADE=SU(NI+3,J,K)

T(NI+3,J,K)=TOD(NI+3,J,K)+DTIME\*(QCONW+QCONE+QRADE)/  
& (VOL\*CPM(NI+3,J,K))

T(NI+4,J,K)=(2.0\*COND(NI+3,J,K)\*T(NI+3,J,K)+HCOEF\*TINF\*DXI)/  
& (HCOEF\*DXI+2.0\*COND(NI+3,J,K))

QSCONE=QSCONE+QCONW  
QSRADW=QSRADW+QRADE

80 CONTINUE

C \*\*\* CALCULATE THE ENERGY LOST THROUGH (OR CONSUMED BY)  
C 1) THE CAVITY WALLS; 2) CAVITY AIR; 3) DUCT

C \*\*\* TANK AIR

WERR=0.

WAIR=0.

DO 25 I=3,NI+2

DO 25 J=3,NJ+2

DO 25 K=3,NK+2

IF(NOD(I,J,K).EQ.1) GO TO 25

DXI=DXXC(I)

DYJ=DYYC(J)

DZK=DZZC(K)

C \*\*\* CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME

DXP1=DXXC(I+1)

DXI =DXXC(I)

DXM1=DXXC(I-1)

DYP1=DYYC(J+1)

DYJ =DYYC(J)

DYM1=DYYC(J-1)

DZP1=DZZC(K+1)

DZK =DZZC(K)

DZM1=DZZC(K-1)

C \*\*\* SURFACE LENGTH OF THE CONTROL VOLUME

DXN=DXXC(I)

DXS=DXXC(I)

```

DXF=DXXC(I)
DXB=DXXC(I)

DYF=DYYC(J)
DYB=DYYC(J)
DYE=DYYC(J)
DYW=DYYC(J)

DZE=DZZC(K)
DZW=DZZC(K)
DZN=DZZC(K)
DZS=DZZC(K)

C **** DEFINE AREA OF THE CONTROL VOLUME
DXYF=DXF*DYF
DXYB=DXB*DYB
DYZE=DYE*DZE
DYZW=DYW*DZW
DZXN=DZN*DXN
DZXS=DZS*DXS

VOL=DXI*DYJ*DZK
VOLDT=VOL/DTIME

RN=(R(I,J,K)*DYP1+R(I,J+1,K)*DYJ)/(DYP1+DYJ)
RS=(R(I,J,K)*DYM1+R(I,J-1,K)*DYJ)/(DYM1+DYJ)
RE=(R(I,J,K)*DXP1+R(I+1,J,K)*DXI)/(DXP1+DXI)
RW=(R(I,J,K)*DXM1+R(I-1,J,K)*DXI)/(DXM1+DXI)
RF=(R(I,J,K)*DZP1+R(I,J,K+1)*DZK)/(DZP1+DZK)
RB=(R(I,J,K)*DZM1+R(I,J,K-1)*DZK)/(DZM1+DZK)

CN=RN*V(I,J+1,K)*DZXN
CS=RS*V(I,J-1,K)*DZXS
CE=RE*U(I+1,J,K)*DYZE
CW=RW*U(I-1,J,K)*DYZW
CF=RF*W(I,J,K+1)*DXYF
CB=RB*W(I,J,K-1)*DXYB

WERR=WERR+T(I,J,K)*CPM(I,J,K)*SMP(I,J,K)
WRES=WRES+SMP(I,J,K)
WAIR=WAIR+(T(I,J,K)*R(I,J,K)-TOD(I,J,K)*ROD(I,J,K))*CPM(I,J,K)*VOLDT
&
25 CONTINUE

C *** SUM UP THE TOTAL WALT AT THAT TIME STEP (DIMENSIONLESS)
WINS=QQQ/H**3

C *** SUM UP THE TOTAL WALT LOST TO THE WALLS
QTCON=QSCONF+QSCONF+QSCONS+QSCONN+QSCONN+QSCONN+QSCONF
QTRAD=QSRADF+QSRADB+QSRADS+QSRADN+QSRADW+QSRADW
WWAL=QTCON+QTRAD

C *** EQUIVALENT INTERNAL HEAT SOURCE DUE TO RADIATION
QR=QTRAD*U0*CP0*RHO0*TA*H**2

C *** TOTAL WALT EXHAUSTED THROUGH THE DUCT

```

```

IF (NMS.EQ.0) THEN
  WWFAN=0.0
ELSE
  WWFAN=8000.*CPM(12,3,12)*(T(12,3,12)-1.0)*R(12,3,12)/
&           (60.*H**2*U0)
ENDIF

C *** THE ENERGY CALCULATION
QSIN=QSIN+WINS*DTIME
QSWER=QSWER+WERR*DTIME
QSWAL=QSWAL+WWAL*DTIME
QSAIR=QSAIR+WAIR*DTIME
QSFAN=QSFAN+WWFAN*DTIME

RETURN
END

*****
***** SUBROUTINE CALU *****
***** *CALCULATES THE U COMPONENT OF THE VELOCITY

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&           DYYC(40),DZZC(40),DXXS(40),DYYs(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL20/SIG11(25,25,15),SIG12(25,25,15),SIG22(25,25,15),
&           SIG13(25,25,15),SIG23(25,25,15),SIG33(25,25,15)
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
&           JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),
&           COD(25,25,15),UOD(25,25,15),VOD(25,25,15),
&           WOD(25,25,15)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&           U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL33/TPD(25,25,15),RPD(25,25,15),PPD(25,25,15),
&           CPD(25,25,15),UPD(25,25,15),VPD(25,25,15),
&           WPD(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
&           SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
&           DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
&           AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
&           SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&           CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)

C *** CALCULATE COEFFICIENTS
DO 100 K=2,NK+3
DO 100 J=2,NJ+3
DO 100 I=3,NI+3

C *** CENTRAL LENGTH OF THE U CONTROL VOLUME
DXP1=DXXS(I+1)

```

```
DXI =DXXS(I)
DXM1=DXXS(I-1)
```

```
DYP1=DYYC(J+1)
DYJ =DYYC(J)
DYM1=DYYC(J-1)
```

```
DZP1=DZZC(K+1)
DZK =DZZC(K)
DZM1=DZZC(K-1)
```

```
C *** SURFACE LENGTH OF THE CONTROL VOLUME
```

```
DXN=DXXS(I)
DXS=DXXS(I)
DXF=DXXS(I)
DXB=DXXS(I)
```

```
DYF=DYYC(J)
DYB=DYYC(J)
DYE=DYYC(J)
DYW=DYYC(J)
```

```
DZE=DZZC(K)
DZW=DZZC(K)
DZN=DZZC(K)
DZS=DZZC(K)
```

```
C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR U
```

```
DXEE=DXXC(I+1)
DXE =DXXC(I)
DXW =DXXC(I-1)
DXWW=DXXC(I-2)
```

```
DYNN=DYYS(J+2)
DYN =DYYS(J+1)
DYS =DYYS(J)
DYSS=DYYS(J-1)
```

```
DZFF=DZZS(K+2)
DZF =DZZS(K+1)
DZB =DZZS(K)
DZBB=DZZS(K-1)
```

```
C *** DEFINE THE AREA OF THE CONTROL VOLUME
```

```
DXYF=DXF*DYF
DXYB=DXB*DYB
DYZE=DYE*DZE
DYZW=DYW*DZW
DZXN=DZN*DXN
DZXS=DZS*DXS
```

```
VOL=DXI*DYJ*DZK
VOLDT=VOL/DTIME
```

```
ZXOYN=DZXN/DYN
ZXOYS=DZXS/DYS
```

```

XYOZF=DXYF/DZF
XYOZB=DXYB/DZB
YZOXE=DYZE/DXE
YZOXW=DYZW/DXW

```

```

C *** USE SINGLE AND BI-LINEAR INTERPOLATION TO EVALUATE
C PHYSICAL PROPERTIES AND FLUX ON THE SURFACES.

```

```

GNE=SILIN(R(I ,J+1,K),R(I ,J,K),DYP1,DYJ)*V(I ,J+1,K)
GNW=SILIN(R(I-1,J+1,K),R(I-1,J,K),DYP1,DYJ)*V(I-1,J+1,K)
GSE=SILIN(R(I ,J-1,K),R(I ,J,K),DYM1,DYJ)*V(I ,J ,K)
GSW=SILIN(R(I-1,J-1,K),R(I-1,J,K),DYM1,DYJ)*V(I-1,J ,K)

```

```

GE =SILIN(R(I+1,J,K),R(I ,J,K),DXEE,DXE)*U(I+1,J,K)
GP =SILIN(R(I-1,J,K),R(I ,J,K),DXW ,DXE)*U(I ,J,K)
GW =SILIN(R(I-2,J,K),R(I-1,J,K),DXWW,DXW)*U(I-1,J,K)

```

```

GFE=SILIN(R(I ,J,K+1),R(I ,J,K),DZP1,DZK)*W(I ,J,K+1)
GFW=SILIN(R(I-1,J,K+1),R(I-1,J,K),DZP1,DZK)*W(I-1,J,K+1)
GBE=SILIN(R(I ,J,K-1),R(I ,J,K),DZM1,DZK)*W(I ,J,K )
GBW=SILIN(R(I-1,J,K-1),R(I-1,J,K),DZM1,DZK)*W(I-1,J,K )

```

```

C *** MASS FLOW RATE

```

```

CE=0.5*(GE+GP)*DYZE
CW=0.5*(GP+GW)*DYZW

```

```

CN=SILIN(GNE,GNW,DXE,DXW)*DZVN
CS=SILIN(GSE,GSW,DXE,DXW)*DZVS

```

```

CF=SILIN(GFE,GFW,DXE,DXW)*DXYF
CB=SILIN(GBE,GBW,DXE,DXW)*DXYB

```

```

C *** VISCOSITY

```

```

VISE=VIS(I ,J,K)
VISW=VIS(I-1,J,K)

```

```

VISN=(VIS(I ,J+1,K)+VIS(I ,J,K)+VIS(I-1,J+1,K)+VIS(I-1,J,K))/4.0
VISS=(VIS(I ,J-1,K)+VIS(I ,J,K)+VIS(I-1,J-1,K)+VIS(I-1,J,K))/4.0

```

```

VISF=(VIS(I ,J,K+1)+VIS(I ,J,K)+VIS(I-1,J,K+1)+VIS(I-1,J,K))/4.0
VISB=(VIS(I ,J,K-1)+VIS(I ,J,K)+VIS(I-1,J,K-1)+VIS(I-1,J,K))/4.0

```

```

VISN1=ZXOYN*VISN
VISS1=ZXOYS*VISS
VISE1=YZOXE*VISE
VISW1=YZOXW*VISW
VISF1=XYOZF*VISF
VISB1=XYOZB*VISB

```

```

C *** QUICK SCHEME

```

```

CEP=(ABS(CE)+CE)*DXE/(DXI *16.)
CEM=(ABS(CE)-CE)*DXE/(DXP1*16.)
CWP=(ABS(CW)+CW)*DXW/(DXM1*16.)
CWM=(ABS(CW)-CW)*DXW/(DXI *16.)

```

```

CNP=(ABS(CN)+CN)*DYP1*DYJ/(8.*DYN*(DYN+DYS ))
CNM=(ABS(CN)-CN)*DYP1*DYJ/(8.*DYN*(DYN+DYN))

```

$CSP = (ABS(CS) + CS) * DYM1 * DYJ / (8. * DYS * (DYS + DYSS))$   
 $CSM = (ABS(CS) - CS) * DYM1 * DYJ / (8. * DYS * (DYS + DYN))$

$CFP = (ABS(CF) + CF) * DZP1 * DZK / (8. * DZF * (DZF + DZB))$   
 $CFM = (ABS(CF) - CF) * DZP1 * DZK / (8. * DZF * (DZF + DZFF))$   
 $CBP = (ABS(CB) + CB) * DZM1 * DZK / (8. * DZB * (DZB + DZBB))$   
 $CBM = (ABS(CB) - CB) * DZM1 * DZK / (8. * DZB * (DZB + DZF))$

$AE(I, J, K) = - .5 * CE + CWM * DXW / DXE + CEP + CEM * (1. + DXE / DXEE) + VISE1$   
 $AW(I, J, K) = .5 * CW + CEP * DXE / DXW + CWM + CWP * (1. + DXW / DXWW) + VISW1$   
 $AN(I, J, K) = (- .5 * CN * DYJ + CSM * DYS) / DYN + CNP + CNM * (1. + DYN / DYN) + VISP1$   
 $AS(I, J, K) = (.5 * CS * DYJ + CNP * DYN) / DYS + CSM + CSP * (1. + DYS / DYSS) + VISS1$   
 $AF(I, J, K) = (- .5 * CF * DZK + CBM * DZB) / DZF + CFP + CFM * (1. + DZF / DZFF) + VISF1$   
 $AB(I, J, K) = (.5 * CB * DZK + CFP * DZF) / DZB + CBM + CBP * (1. + DZB / DZBB) + VISB1$

C \*\*\*\* BOUNDARY CONSIDERATION

```

IF (I.LT.NI+3) THEN
  AEE=-CEM*DXE/DXEE
  AEER=AEE*UPD(I+2,J,K)
ELSE
  AEE=0.
  AEER=0.
ENDIF

```

```

IF (I.GT.3) THEN
  AWW=-CWP*DXW/DXWW
  AWWR=AWW*UPD(I-2,J,K)
ELSE
  AWW=0.
  AWWR=0.
ENDIF

```

```

IF (J.LT.NJ+3) THEN
  ANN=-CNM*DYN/DYNN
  ANNR=ANN*UPD(I,J+2,K)
ELSE
  ANN=0.
  ANNR=0.
ENDIF

```

```

IF (J.GT.2) THEN
  ASS=-CSP*DYS/DYSS
  ASSR=ASS*UPD(I,J-2,K)
ELSE
  ASS=0.
  ASSR=0.
ENDIF

```

```

IF (K.LT.NK+3) THEN
  AFF=-CFM*DZF/DZFF
  AFFR=AFF*UPD(I,J,K+2)
ELSE
  AFF=0.
  AFFR=0.
ENDIF

```

```

    IF (K.GT.2) THEN
        ABB=-CBP*DZB/DZBB
        ABBR=ABB*UPD(I,J,K-2)
    ELSE
        ABB=0.
        ABBR=0.
    ENDIF

C *** MODIFICATION FOR DECK BOUNDARIES
    IF (NOD(I-2,J,K).NE.0) THEN
        AWW=0.0
        AWWR=0.0
    ENDIF

    IF (NOD(I+1,J,K).NE.0) THEN
        AEE=0.0
        AEER=0.0
    ENDIF

    IF (NOD(I,J-1,K).NE.0) THEN
        ASS=0.0
        ASSR=0.0
    ENDIF

    IF (NOD(I,J+1,K).NE.0) THEN
        ANN=0.0
        ANNR=0.0
    ENDIF

    IF (NOD(I,J,K-1).NE.0) THEN
        ABB=0.0
        ABBR=0.0
    ENDIF

    IF (NOD(I,J,K+1).NE.0) THEN
        AFF=0.0
        AFFR=0.0
    ENDIF

C *** SU FROM NORMAL STRESS
    RE=(SIG11(I,J,K)-(U(I+1,J,K)-U(I,J,K))*VISE/DXE)*DYZE
    RW=(SIG11(I-1,J,K)-(U(I,J,K)-U(I-1,J,K))*VISW/DXW)*DYZW

    RN=(SIG12(I,J+1,K)-(U(I,J+1,K)-U(I,J,K))*VISN/DYN)*DZXX
    RS=(SIG12(I,J,K)-(U(I,J,K)-U(I,J-1,K))*VISS/DYS)*DZXS

    RF=(SIG13(I,J,K+1)-(U(I,J,K+1)-U(I,J,K))*VISF/DZF)*DXYF
    RB=(SIG13(I,J,K)-(U(I,J,K)-U(I,J,K-1))*VISB/DZB)*DXYB

C *** SU FROM CURVED STRESSES AND ACCELERATIONS
    AVG12=0.5*(SIG12(I,J+1,K)+SIG12(I,J,K))
    AVG13=0.5*(SIG13(I,J,K+1)+SIG13(I,J,K))

    AVG22=SILIN(SIG22(I,J,K),SIG22(I-1,J,K),DXE,DXW)
    AVG33=SILIN(SIG33(I,J,K),SIG33(I-1,J,K),DXE,DXW)

```

```

AU1=U(I,J,K)
AU2=BILIN(V(I,J+1,K),V(I,J,K),DYJ,DYJ,
&           V(I-1,J+1,K),V(I-1,J,K),DYJ,DYJ,DXE,DXW)
&           AU3=BILIN(W(I,J,K+1),W(I,J,K),DZK,DZK,
&           W(I-1,J,K+1),W(I-1,J,K),DZK,DZK,DXE,DXW)

AR=SILIN(R(I,J,K),R(I-1,J,K),DXE,DXW)

ARU12=AR*AU1*AU2
ARU13=AR*AU1*AU3
ARU22=AR*AU2*AU2
ARU33=AR*AU3*AU3

RRY=(AVG12-ARU12)*DZK*(DXN-DXS)
RRZ=(AVG13-ARU13)*DYJ*(DXF-DBX)
RRX=(AVG22-ARU22)*DZK*(DYE-DYW)+(AVG33-ARU33)*DYJ*(DZE-DZW)

AP(I,J,K)=AE(I,J,K)+AW(I,J,K)+AN(I,J,K)+AS(I,J,K)+AF(I,J,K)+
&           AB(I,J,K)+AEE+AWW+ANN+ASS+AFF+ABB
SP(I,J,K)=-(ROD(I,J,K)*DXW+ROD(I-1,J,K)*DXE)*VOLDT/(DXW+DXE)
SU(I,J,K)=-SP(I,J,K)*UOD(I,J,K)+DYJ*DZK*(P(I-1,J,K)-P(I,J,K))+
&           AEER+AWWR+ANNR+ASSR+AFFR+ABBR+RE-RW+RN-RS+RF-RB+RRY+
&           RRZ-RRX
100 CONTINUE

C **** TAKE CARE OF B.C. THRU AN,AS,AE,AW,AF,AB,SP AND SU

C **** Y DIRECTION
DO 500 K=2,NK+3
DO 500 I=3,NI+3
  SP(I,2,K)=SP(I,2,K)-AS(I,2,K)
  SP(I,NJ+3,K)=SP(I,NJ+3,K)-AN(I,NJ+3,K)
  AN(I,NJ+3,K)=0.
  AS(I,2,K)=0.
500 CONTINUE

C **** X DIRECTION
DO 502 K=2,NK+3
DO 502 J=2,NJ+3
  AW(3,J,K)=0.0
  AE(NI+3,J,K)=0.0
502 CONTINUE

C **** Z DIRECTION
DO 600 I=3,NI+3
DO 600 J=2,NJ+3
  SP(I,J,2)=SP(I,J,2)-AB(I,J,2)
  SP(I,J,NK+3)=SP(I,J,NK+3)-AF(I,J,NK+3)
  AF(I,J,NK+3)=0.
  AB(I,J,2)=0.
600 CONTINUE

C **** MODIFICATION FOR DECK BOUNDARIES
IF (NCHIP.EQ.0) GOTO 201
DO 101 N=1,NCHIP
  IB =ICHPB(N)

```

```

IE =IB+NCHPI(N)-1
JB =JCHPB(N)
JE =JB+NCHPJ(N)-1
KB =KCHPB(N)
KE =KB+NCHPK(N)-1

DO 102 J=JB,JE-1
DO 102 K=KB,KE-1
    AE(IB-1,J,K)=0.0
    AW(IE+1,J,K)=0.0
102    CONTINUE

DO 103 I=IB,IE
DO 103 K=KB,KE-1
    SP(I,JB-1,K)=SP(I,JB-1,K)-AN(I,JB-1,K)
    AN(I,JB-1,K)=0.0
    SP(I,JE    ,K)=SP(I,JE    ,K)-AS(I,JE    ,K)
    AS(I,JE    ,K)=0.0
103    CONTINUE

DO 106 I=IB,IE
DO 106 J=JB,JE-1
    SP(I,J,KB-1)=SP(I,J,KB-1)-AF(I,J,KB-1)
    AF(I,J,KB-1)=0.0
    SP(I,J,KE    )=SP(I,J,KE    )-AB(I,J,KE    )
    AB(I,J,KE    )=0.0
106    CONTINUE

C **** FOR THE CELLS INSIDE OF THE DECKS
DO 104 I=IB,IE
DO 104 J=JB,JE-1
DO 104 K=KB,KE-1
    SP(I,J,K)=-1.0E2
    AW(I,J,K)=0.
    AE(I,J,K)=0.
    AS(I,J,K)=0.
    AN(I,J,K)=0.
    AB(I,J,K)=0.
    AF(I,J,K)=0.
    SU(I,J,K)=0.
104    CONTINUE
101    CONTINUE

C **** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS
201 DO 301 K=2,NK+3
    DO 301 J=2,NJ+3
    DO 301 I=3,NI+3
        DYJ=DYYC(J)
        DZK=DZZC(K)
        DYZ=DYJ*DZK
        AP(I,J,K)=AP(I,J,K)-SP(I,J,K)
        DU(I,J,K)=DYZ/AP(I,J,K)
301    CONTINUE

C **** SOLVE FOR U
    CALL TRID (4,3,3,NI+2,NJ+2,NK+2,U)

```

```

C *** RESET THE VELOCITY INSIDE OF DECK
IF (NCHIP.EQ.0) GOTO 111
DO 110 N=1,NCHIP
  IB=ICHPB(N)
  IE=IB+NCHPI(N)-1
  JB=JCHPB(N)
  JE=JB+NCHPJ(N)-1
  KB=KCHPB(N)
  KE=KB+NCHPK(N)-1
  DO 108 I=IB,IE
  DO 108 J=JB,JE-1
  DO 108 K=KB,KE-1
    U(I,J,K)=0.0
108    CONTINUE
110    CONTINUE

111  RETURN
      END

```

```
*****
```

```

      SUBROUTINE CALV
*****
```

```

*CALCULATES THE V COMPONENT OF THE VELOCITY
```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&          DYYC(40),DZZC(40),DXXS(40),DYYs(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL20/SIG11(25,25,15),SIG12(25,25,15),SIG22(25,25,15),
&          SIG13(25,25,15),SIG23(25,25,15),SIG33(25,25,15)
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
&          JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),
&          COD(25,25,15),UOD(25,25,15),VOD(25,25,15),
&          WOD(25,25,15)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&          U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL33/TPD(25,25,15),RPD(25,25,15),PPD(25,25,15),
&          CPD(25,25,15),UPD(25,25,15),VPD(25,25,15),
&          WPD(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
&          SMP(25,25,15),PP(25,25,15),DU(25,25,15),
&          DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
&          AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
&          SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&          CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)

```

```

C *** CALCULATE COEFFICIENTS
DO 100 K=2,NK+3
DO 100 J=3,NJ+3
DO 100 I=2,NI+3

```

```

C **** CENTRAL LENGTH OF THE V CONTROL VOLUME
  DXP1=DXXC(I+1)
  DXI =DXXC(I)
  DXM1=DXXC(I-1)

  DYP1=DYY(S(J+1)
  DYJ =DYY(S(J)
  DYM1=DYY(S(J-1)

  DZP1=DZZC(K+1)
  DZK =DZZC(K)
  DZM1=DZZC(K-1)

C **** SURFACE LENGTH OF THE CONTROL VOLUME
  DXN=DXXC(I)
  DXS=DXXC(I)
  DXF=DXXC(I)
  DXB=DXXC(I)

  DYF=DYY(S(J)
  DYB=DYY(S(J)
  DYE=DYY(S(J)
  DYW=DYY(S(J)

  DZE=DZZC(K)
  DZW=DZZC(K)
  DZN=DZZC(K)
  DZS=DZZC(K)

C **** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR V
  DXEE=DXXS(I+2)
  DXE =DXXS(I+1)
  DXW =DXXS(I)
  DXWW=DXXS(I-1)

  DYNN=DYYC(J+1)
  DYN =DYYC(J)
  DYS =DYYC(J-1)
  DYSS=DYYC(J-2)

  DZFF=DZZC(K+2)
  DZF =DZZC(K+1)
  DZB =DZZC(K)
  DZBB=DZZC(K-1)

C **** DEFINE THE AREA OF THE CONTROL VOLUME
  DXYF=DXF*DYF
  DXYB=DXB*DYB
  DYZE=DYE*DZE
  DYZW=DYW*DZW
  DZXN=DZN*DXN
  DZXS=DZS*DXS

  VOL =DXI*DYJ*DZK
  VOLDT=VOL/DTIME

```

```

ZXOYN=DZXN/DYN
ZXOYS=DZXS/DYS
XYOZF=DXYF/DZF
XYOZB=DXYB/DZB
YZOXE=DYZE/DXE
YZOXW=DYZW/DXW

```

```

C **** USE SINGLE AND BI-LINEAR INTERPOLATION TO EVALUATE
C PHYSICAL PROPERTIES AND FLUX ON THE SURFACES.

```

```

GEN=SILIN(R(I+1,J ,K),R(I,J ,K),DXP1,DXI)*U(I+1,J ,K)
GES=SILIN(R(I+1,J-1,K),R(I,J-1,K),DXP1,DXI)*U(I+1,J-1,K)
GWN=SILIN(R(I-1,J ,K),R(I,J ,K),DXM1,DXI)*U(I ,J ,K)
GWS=SILIN(R(I-1,J-1,K),R(I,J-1,K),DXM1,DXI)*U(I ,J-1,K)

```

```

GN =SILIN(R(I,J+1,K),R(I,J ,K),DYN, DYN)*V(1,J+1,K)
GP =SILIN(R(I,J-1,K),R(I,J ,K),DYS , DYN)*V(I,J ,K)
GS =SILIN(R(I,J-2,K),R(I,J-1,K),DYSS,DYS)*V(I,J-1,K)

```

```

GFN=SILIN(R(I,J ,K+1),R(I,J ,K),DZP1,DZK)*W(I,J ,K+1)
GFS=SILIN(R(I,J-1,K+1),R(I,J-1,K),DZP1,DZK)*W(I,J-1,K+1)
GBN=SILIN(R(I,J ,K-1),R(I,J ,K),DZM1,DZK)*W(I,J ,K )
GBS=SILIN(R(I,J-1,K-1),R(I,J-1,K),DZM1,DZK)*W(I,J-1,K )

```

```

C **** MASS FLOW RATE

```

```

CN=0.5*(GN+GP)*DZXN
CS=0.5*(GP+GS)*DZXS
CE=SILIN(GEN,GES,DYN,DYS)*DYZE
CW=SILIN(GWN,GWS,DYN,DYS)*DYZW
CF=SILIN(GFN,GFS,DYN,DYS)*DXYF
CB=SILIN(GBN,GBS,DYN,DYS)*DXYB

```

```

C **** VISCOSITY

```

```

VISN= VIS(I,J ,K)
VISS= VIS(I,J-1,K)
VISE=(VIS(I+1,J,K)+VIS(I,J,K)+VIS(I+1,J-1,K)+VIS(I,J-1,K))/4.0
VISW=(VIS(I-1,J,K)+VIS(I,J,K)+VIS(I-1,J-1,K)+VIS(I,J-1,K))/4.0
VISF=(VIS(I,J,K+1)+VIS(I,J,K)+VIS(I,J-1,K+1)+VIS(I,J-1,K))/4.0
VISB=(VIS(I,J,K-1)+VIS(I,J,K)+VIS(I,J-1,K-1)+VIS(I,J-1,K))/4.0

```

```

VISN1=ZXOYN*VISN
VISS1=ZXOYS*VISS
VISE1=YZOXE*VISE
VISW1=YZOXW*VISW
VISF1=XYOZF*VISF
VISB1=XYOZB*VISB

```

```

C **** QUICK SCHEME

```

```

CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW )*8.)
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXEE)*8.)
CWP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXWW)*8.)
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DXE )*8.)

```

```

CNP=(ABS(CN)+CN)*DYN/(DYJ *16.)
CNM=(ABS(CN)-CN)*DYN/(DYP1*16.)
CSP=(ABS(CS)+CS)*DYS/(DYM1*16.)

```

```

CSM=(ABS(CS)-CS)*DYS/(DYJ *16.)

CFP=(ABS(CF)+CF)*DZP1*DZK/(DZF*(DZF+DZB )*8.)
CFM=(ABS(CF)-CF)*DZP1*DZK/(DZF*(DZF+DZFF)*8.)
CBP=(ABS(CB)+CB)*DZM1*DZK/(DZB*(DZB+DZBB)*8.)
CBM=(ABS(CB)-CB)*DZM1*DZK/(DZB*(DZB+DZF )*8.)

AE(I,J,K)=(- .5*CE*DXI+CWM*DXW)/DXE+CEP+CEM*(1.+DXE/DXEE)+VISE1
AW(I,J,K)=(- .5*CW*DXI+CEP*DXE)/DXW+CWM+CWP*(1.+DXW/DXWW)+VISW1
AN(I,J,K)= - .5*CN      +CSM*DYS /DYN+CNP+CNM*(1.+DYN/DYNN)+VISN1
AS(I,J,K)= .5*CS      +CNP*DYN /DYS+CSM+CSP*(1.+DYS/DYSS)+VISS1
AF(I,J,K)=(- .5*CF*DZK+CBM*DZB)/DZF+CFP+CFM*(1.+DZF/DZFF)+VISF1
AB(I,J,K)=( .5*CB*DZK+CFP*DZF)/DZB+CBM+CBP*(1.+DZB/DZBB)+VISB1

C *** BOUNDARY CONSIDERATION
IF (I.LT.NI+3) THEN
  AEE=-CEM*DXE/DXEE
  AEER=AEE*VPD(I+2,J,K)
ELSE
  AEE=0.
  AEER=0.
ENDIF

IF (I.GT.2) THEN
  AWW=-CWP*DXW/DXWW
  AWWR=AWW*VPD(I-2,J,K)
ELSE
  AWW=0.
  AWWR=0.
ENDIF

IF (J.LT.NJ+3) THEN
  ANN=-CNM*DYN/DYNN
  ANNR=ANN*VPD(I,J+2,K)
ELSE
  ANN=0.
  ANNR=0.
ENDIF

IF (J.GT.3) THEN
  ASS=-CSP*DYS/DYSS
  ASSR=ASS*VPD(I,J-2,K)
ELSE
  ASS=0.
  ASSR=0.
ENDIF

IF (K.LT.NK+3) THEN
  AFF=-CFM*DZF/DZFF
  AFFR=AFF*VPD(I,J,K+2)
ELSE
  AFF=0.
  AFFR=0.
ENDIF

IF (K.GT.2) THEN

```

```

        ABB=-CBP*DZB/DZBB
        ABBR=ABB*VPD(I,J,K-2)
    ELSE
        ABB=0.
        ABBR=0.
    ENDIF

C **** MODIFICATION FOR DECK BOUNDARIES
    IF (NOD(I-1,J,K).NE.0) THEN
        AWW=0.0
        AWWR=0.0
    ENDIF

    IF (NOD(I+1,J,K).NE.0) THEN
        AEE=0.0
        AEER=0.0
    ENDIF

    IF (NOD(I,J-2,K).NE.0) THEN
        ASS=0.0
        ASSR=0.0
    ENDIF

    IF (NOD(I,J+1,K).NE.0) THEN
        ANN=0.0
        ANNR=0.0
    ENDIF

    IF (NOD(I,J,K-1).NE.0) THEN
        ABB=0.0
        ABBR=0.0
    ENDIF

    IF (NOD(I,J,K+1).EQ.0) THEN
        AFF=0.0
        AFFR=0.0
    ENDIF

C **** SU FROM NORMAL STRESS
    RN=(SIG22(I,J,K)-(V(I,J+1,K)-V(I,J,K))*VISN/DYN)*DZBN
    RS=(SIG22(I,J-1,K)-(V(I,J,K)-V(I,J-1,K))*VISS/DYS)*DZBS
    RE=(SIG12(I+1,J,K)-(V(I+1,J,K)-V(I,J,K))*VISE/DXE)*DYZE
    RW=(SIG12(I,J,K)-(V(I,J,K)-V(I-1,J,K))*VISW/DXW)*DYZW
    RF=(SIG23(I,J,K+1)-(V(I,J,K+1)-V(I,J,K))*VISF/DZF)*DXYF
    RB=(SIG23(I,J,K)-(V(I,J,K)-V(I,J,K-1))*VISB/DZB)*DXYB

C **** SU FROM CURVED STRESSES AND ACCELERATIONS
    AVG12= 0.5*(SIG12(I+1,J,K)+SIG12(I,J,K))
    AVG23= 0.5*(SIG23(I,J,K+1)+SIG23(I,J,K))
    AVG11=SILIN(SIG11(I,J,K),SIG11(I,J-1,K),DYN,DYS)
    AVG33=SILIN(SIG33(I,J,K),SIG33(I,J-1,K),DYN,DYS)

    AU2=V(I,J,K)
    AU1=BILIN(U(I+1,J,K),U(I,J,K),DXI,DXI,
    &           U(I+1,J-1,K),U(I,J-1,K),DXI,DXI,DYN,DYS)
    AU3=BILIN(W(I,J,K+1),W(I,J,K),DZK,DZK,

```

```

&           W(I    ,J-1,K+1),W(I,J-1,K),DZK,DZK,DYN,DYS)

AR=SILIN(R(I,J,K),R(I,J-1,K),DYN,DYS)

ARU12=AR*AU1*AU2
ARU23=AR*AU2*AU3
ARU11=AR*AU1*AU1
ARU33=AR*AU3*AU3

RRX=(AVG12-ARU12)*DZK*(DYE-DYW)
RRZ=(AVG23-ARU23)*DXI*(DYF-DYB)
RRY=(AVG11-ARU11)*DZK*(DXN-DXS)+(AVG33-ARU33)*DXI*(DZN-DZS)

AP(I,J,K)=AE(I,J,K)+AW(I,J,K)+AN(I,J,K)+AS(I,J,K)+  

&           AF(I,J,K)+AB(I,J,K)+AEE+AWW+ANN+ASS+AFF+ABB  

&           SP(I,J,K)=-(ROD(I,J,K)*DYS+ROD(I,J-1,K)*DYN)*VOLDT/(DYS+DYN)  

&           SU(I,J,K)=-SP(I,J,K)*VOD(I,J,K)+DZK*DXI*(P(I,J-1,K)-P(I,J,K))+  

&           AEER+AWWR+ANNR+ASSR+AFFR+ABBR+RE-RW+RN-RS+RF-RB+RRX+  

&           RRZ-RRY
100 CONTINUE

C *** TAKE CARE OF B.C. THRU AN,AS,AE,AW,AF,AB,SP AND SU

C *** Y DIRECTION
DO 500 K=2,NK+3
DO 500 I=2,NI+3
  AS(I,3    ,K)=0.
  AN(I,NJ+3,K)=0.
500 CONTINUE

C *** X DIRECTION
DO 502 K=2,NK+3
DO 502 J=3,NJ+3
  SP(2    ,J,K)=SP(2    ,J,K)-AW(2    ,J,K)
  SP(NI+3,J,K)=SP(NI+3,J,K)-AE(NI+3,J,K)
  AW(2    ,J,K)=0.0
  AE(NI+3,J,K)=0.0
502 CONTINUE

C *** Z DIRECTION
DO 600 I=2,NI+3
DO 600 J=3,NJ+3
  SP(I,J,2    )=SP(I,J,2    )-AB(I,J,2    )
  SP(I,J,NK+3)=SP(I,J,NK+3)-AF(I,J,NK+3)
  AF(I,J,NK+3)=0.
  AB(I,J,2    )=0.
600 CONTINUE

C *** MODIFICATION FOR DECK BOUNDARIES
IF (NCHIP.EQ.0) GOTO 201
DO 101 N=1,NCHIP
  IB  =ICHBPB(N)
  IE  =IB+NCHPI(N)-1
  JB  =JCHPB(N)
  JE  =JB+NCHPJ(N)-1
  KB  =KCHPB(N)

```

```

      KE =KB+NCHPK(N)-1
      DO 102 J=JB,JE
      DO 102 K=KB,KE-1
          SP(IB-1,J,K)=SP(IB-1,J,K)-AE(IB-1,J,K)
          AE(IB-1,J,K)=0.0
          SP(IE  ,J,K)=SP(IE  ,J,K)-AW(IE  ,J,K)
          AW(IE  ,J,K)=0.0
102    CONTINUE

      DO 103 I=IB,IE-1
      DO 103 K=KB,KE-1
          AN(I,JB-1,K)=0.0
          AS(I,JE+1,K)=0.0
103    CONTINUE

      DO 106 I=IB,IE-1
      DO 106 J=JB,JE
          SP(I,J,KB-1)=SP(I,J,KB-1)-AF(I,J,KB-1)
          AF(I,J,KB-1)=0.0
          SP(I,J,KE  )=SP(I,J,KE  )-AB(I,J,KE  )
          AB(I,J,KE  )=0.0
106    CONTINUE

C **** MODIFICATION FOR THE CELLS INSIDE OF THE DECKS
      DO 104 I=IB,IE-1
      DO 104 J=JB,JE
      DO 104 K=KB,KE-1
          SP(I,J,K)=-1.0E2
          AW(I,J,K)=0.
          AE(I,J,K)=0.
          AS(I,J,K)=0.
          AN(I,J,K)=0.
          AB(I,J,K)=0.
          AF(I,J,K)=0.
          SU(I,J,K)=0.
104    CONTINUE
101    CONTINUE

C **** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS
201  DO 300 K=2,NK+3
      DO 300 J=3,NJ+3
      DO 300 I=2,NI+3
          DXI=DXXC(I)
          DZK=DZZC(K)
          DZX=DZK*DXI
          AP(I,J,K)=AP(I,J,K)-SP(I,J,K)
          DV(I,J,K)=DZX/AP(I,J,K)
300    CONTINUE

C **** SOLVE FOR V
      CALL TRID (3,4,3,NI+2,NJ+2,NK+2,V)

C **** RESET THE VELOCITY INSIDE OF THE DECKS
      IF (NCHIP.EQ.0) GOTO 111
      DO 110 N=1,NCHIP
          IB=ICHPB(N)

```

```

IE=IB+NCHPI(N)-1
JB=JCHPB(N)
JE=JB+NCHPJ(N)-1
KB=KCHPB(N)
KE=KB+NCHPK(N)-1
DO 108 I=IB,IE-1
DO 108 J=JB,JE
DO 108 K=KB,KE-1
      V(I,J,K)=0.0
108    CONTINUE
110    CONTINUE

111 RETURN
END

```

```
*****
***** SUBROUTINE CALVIS *****
***** THIS SUBROUTINE CALCULATES THE TURBULENT VISCOSITY AND UPDATES *****
***** THE VISCOSITY MATRIX *****
*****
```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&          DYYC(40),DZZC(40),DXXS(40),DYYs(40),DZZS(40)
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL14/HCOEF,CNT,ABTURB,BTURB,VISL,VISMAX
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,COND0,VISO,RHO0,
&          TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&          U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
&          SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
&          DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
&          AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
&          SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&          CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)

```

```

C *** CALCULATE LOCAL SHEAR AND VISCOSITY VIS(I,J,K)

C *** SPECIFY LOCAL TURBULENT LENGTH SCALES SMPP(I,J,K)
DO 611 K=3,NK+2
DO 611 J=3,NJ+2
DO 611 I=3,NI+2

C *** CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME
DXP1=DXXC(I+1)
DXI =DXXC(I)
DXM1=DXXC(I-1)

DYP1=DYYC(J+1)
DYJ =DYYC(J)
DYM1=DYYC(J-1)

```

```

DZP1=DZZC(K+1)
DZK =DZZC(K)
DZM1=DZZC(K-1)

C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T
DXE =DXXS(I+1)
DXW =DXXS(I)

DYN =DYYs(J+1)
DYS =DYYs(J)

DZF =DZZS(K+1)
DZB =DZZS(K)

C *** CACULATE DV/DX, D2V/DX2, DU/DX, D2U/DX2, DW/DX AND D2W/DX2
DUDX = (U(I+1,J,K)-U(I,J,K))/DXI
DUDXW =0.5*(U(I+1,J,K)-U(I-1,J,K))/DXW
DUDXE =0.5*(U(I+2,J,K)-U(I,J,K))/DXE
D2UDX2=(DUDXE-DUDXW)/DXI

DVDXW =0.5*(V(I,J+1,K)+V(I,J,K)-V(I-1,J+1,K)-V(I-1,J,K))/DXW
DVDXE =0.5*(V(I+1,J+1,K)+V(I+1,J,K)-V(I,J+1,K)-V(I,J,K))/DXE
DVDX =0.5*(DVDXE+DVDXW)
D2VDX2= (DVDXE-DVDXW)/DXI

DWDXW =0.5*(W(I,J,K+1)+W(I,J,K)-W(I-1,J,K+1)-W(I-1,J,K))/DXW
DWDXE =0.5*(W(I+1,J,K+1)+W(I+1,J,K)-W(I,J,K+1)-W(I,J,K))/DXE
DWDX =0.5*(DWDXE+DWDXW)
D2WDX2= (DWDXE-DWDXW)/DXI

C *** CALCULATE DU/DY, D2U/DY2, DV/DY, D2V/DY2, DW/DY AND D2W/DY2
DVDY = (V(I,J+1,K)-V(I,J,K))/DYJ
DVDYS =0.5*(V(I,J+1,K)-V(I,J-1,K))/DYS
DVDYN =0.5*(V(I,J+2,K)-V(I,J,K))/DYN
D2VDY2=(DVDYN-DVDYS)/DYJ

DUDYS =0.5*(U(I+1,J,K)+U(I,J,K)-U(I+1,J-1,K)-U(I,J-1,K))/DYS
DUDYN =0.5*(U(I+1,J+1,K)+U(I,J+1,K)-U(I+1,J,K)-U(I,J,K))/DYN
DUDY =0.5*(DUDYN+DUDYS)
D2UDY2= (DUDYN-DUDYS)/DYJ

DWDYS =0.5*(W(I,J,K+1)+W(I,J,K)-W(I,J-1,K+1)-W(I,J-1,K))/DYS
DWDYN =0.5*(W(I,J+1,K+1)+W(I,J+1,K)-W(I,J,K+1)-W(I,J,K))/DYN
DWDY =0.5*(DWDYN+DWDYS)
D2WDY2= (DWDYN-DWDYS)/DYJ

C *** CALCULATE DU/DZ, D2U/DZ2, DV/DZ, D2V/DZ2, DW/DZ AND D2W/DZ2
DWDZ = (W(I,J,K+1)-W(I,J,K))/DZK
DWDZF =0.5*(W(I,J,K+2)-W(I,J,K))/DZF
DWDZB =0.5*(W(I,J,K+1)-W(I,J,K-1))/DZB
D2WDZ2=(DWDZF-DWDZB)/DZK

DVDZB =0.5*(V(I,J+1,K)+V(I,J,K)-V(I,J+1,K-1)-V(I,J,K-1))/DZB
DVDZF =0.5*(V(I,J+1,K+1)+V(I,J,K+1)-V(I,J+1,K)-V(I,J,K))/DZF
DVDZ =0.5*(DVDZF+DVDZB)

```

```

D2VDZ2=      (DVDZF-DVDZB)/DZK

DUDZB =0.5*(U(I+1,J,K)+U(I,J,K)-U(I+1,J,K-1)-U(I,J,K-1))/DZB
DUDZF =0.5*(U(I+1,J,K+1)+U(I,J,K+1)-U(I+1,J,K)-U(I,J,K))/DZF
DUDZ =0.5*(DUDZF+DUDZB)
D2UDZ2=      (DUDZF-DUDZB)/DZK

C *** CALCULATE THE DENSITY GRADIENT WITH RESPECT TO THE VERTICAL
      DRDGA=(R(I,J,K+1)-REQ(I,J,K+1)-R(I,J,K-1)+REQ(I,J,K-1))/(
      &           (DZF+DZB))

C *** CALCULATE STRAIN
      STRAIN=DUDY**2+DVDX**2+Dwdx**2+DVDZ**2+DWDY**2+DUDZ**2
      DD02 =SQRT(STRAIN+DUDX**2+DVDY**2+DWDZ**2)

      IF(DD02.EQ.0..OR.STRAIN.EQ.0.) THEN
          VIS(I,J,K)=VISL
      ELSE

C *** CALCULATE TURBULENT LENGTH SCALE SMPP(I,J)
      SMP123=SQRT(((U(I+1,J,K)+U(I,J,K))/2.)**2+
      &           ((V(I,J+1,K)+V(I,J,K))/2.)**2+
      &           ((W(I,J,K+1)+W(I,J,K))/2.)**2)/DD02
      SMPP12=DD02/SQRT(D2UDX2**2+D2UDY2**2+D2UDZ2**2+D2VDX2**2+
      &           D2VDY2**2+D2VDZ2**2+D2WDZ2**2+D2WDX2**2+D2WDY2**2)
      SMPP(I,J,K)=CNT*(SMP123+SMPP12)/2.

C *** CALCULATE RICHARDSON NUMBER
      RI(I,J,K)=-BUOY*DRDGA/(R(I,J,K)*STRAIN)
      ABRIPR=ABTURB+RI(I,J,K)/PRT

      IF(ABRIPR.LT.0.) THEN
          VIS(I,J,K)=VISL
      ELSEIF(ABRIPR.EQ.0.) THEN
          VIS(I,J,K)=VISMAX
      ELSE
          VIS(I,J,K)=VISL+R(I,J,K)*SMPP(I,J,K)**2*
          &           SQRT(STRAIN)/(BTURB*ABRIPR)
          IF(VIS(I,J,K).GT.VISMAX) VIS(I,J,K)=VISMAX
      ENDIF
      ENDIF
      611 CONTINUE

C *** SPECIFY THE VISCOCITY ON THE BOUNDARY POINT
      DO 110 I=1,NI+4
      DO 110 J=1,NJ+4
          VIS(I,J,NK+3)=VIS(I,J,NK+2)
          VIS(I,J,2      )=VIS(I,J,3      )
110 CONTINUE

      DO 120 J=1,NJ+4
      DO 120 K=1,NK+4
          VIS(NI+3,J,K)=VIS(NI+2,J,K)
          VIS(2      ,J,K)=VIS(3      ,J,K)
120 CONTINUE

```

```

DO 130 K=1,NK+4
DO 130 I=1,NI+4
  VIS(I,NJ+3,K)=VIS(I,NJ+2,K)
  VIS(I,2      ,K)=VIS(I,3      ,K)
130 CONTINUE

C *** CALCULATE TURBULENT CONDUCTIVITY
DO 140 I=1,NI+4
DO 140 J=1,NJ+4
DO 140 K=1,NK+4
  IF (NOD(I,J,K).NE.1) COND(I,J,K)=VIS(I,J,K)/PRT
140 CONTINUE
RETURN
END

*****SUBROUTINE CALW*****
*****CALCULATES THE W COMPONENT OF THE VELOCITY

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&          DYYC(40),DZZC(40),DXXS(40),DYYS(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,COND0,VISO,RH00,
&          TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL20/SIG11(25,25,15),SIG12(25,25,15),SIG22(25,25,15),
&          SIG13(25,25,15),SIG23(25,25,15),SIG33(25,25,15)
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
&          JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),
&          COD(25,25,15),UOD(25,25,15),VOD(25,25,15),
&          WOD(25,25,15)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&          U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL33/TPD(25,25,15),RPD(25,25,15),PPD(25,25,15),
&          CPD(25,25,15),UPD(25,25,15),VPD(25,25,15),
&          WPD(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
&          SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
&          DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
&          AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
&          SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&          CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)

C *** CALCULATE COEFFICIENTS
DO 100 K=3,NK+3
DO 100 J=2,NJ+3
DO 100 I=2,NI+3

C *** CENTRAL LENGTH OF THE W CONTROL VOLUME
DXP1=DXXC(I+1)

```

```
DXI =DXXC(I)
DXM1=DXXC(I-1)
```

```
DYP1=DYYC(J+1)
DYJ =DYYC(J)
DYM1=DYYC(J-1)
```

```
DZP1=DZZS(K+1)
DZK =DZZS(K)
DZM1=DZZS(K-1)
```

```
C *** SURFACE LENGTH OF THE CONTROL VOLUME
```

```
DXN=DXXC(I)
DXS=DXXC(I)
DXF=DXXC(I)
DXB=DXXC(I)
```

```
DYF=DYYC(J)
DYB=DYYC(J)
DYE=DYYC(J)
DYW=DYYC(J)
```

```
DZE=DZZS(K)
DZW=DZZS(K)
DZN=DZZS(K)
DZS=DZZS(K)
```

```
C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME
```

```
DXEE=DXXS(I+2)
DXE =DXXS(I+1)
DXW =DXXS(I)
DXWW=DXXS(I-1)
```

```
DYNN=DYYS(J+2)
DYN =DYYS(J+1)
DYS =DYYS(J)
DYSS=DYYS(J-1)
```

```
DZFF=DZZC(K+1)
DZF =DZZC(K)
DZB =DZZC(K-1)
DZBB=DZZC(K-2)
```

```
C *** DEFINE THE AREA OF THE CONTROL VOLUME
```

```
DXYF=DXF*DYF
DXYB=DXB*DYB
DYZE=DYE*DZE
DYZW=DYW*DZW
DZXN=DZN*DXN
DZXS=DZS*DXS
```

```
VOL=DXI*DYJ*DZK
VOLDT=VOL/DTIME
```

```
ZXOYN=DZXN/DYN
ZXOYS=DZXS/DYS
```

```

XYOZF=DXYF/DZF
XYOZB=DXYB/DZB
YZOXE=DYZE/DXE
YZOXW=DYZW/DXW

```

```

C **** USE SINGLE AND BI-LINEAR INTERPOLATION TO EVALUATE
C      PHYSICAL PROPERTIES AND FLUX ON THE SURFACES.

```

```

GNF=SILIN(R(I,J+1,K ),R(I,J,K ),DYP1,DYJ)*V(I,J+1,K )
GNB=SILIN(R(I,J+1,K-1),R(I,J,K-1),DYP1,DYJ)*V(I,J+1,K-1)
GSF=SILIN(R(I,J-1,K ),R(I,J,K ),DYM1,DYJ)*V(I,J ,K )
GSB=SILIN(R(I,J-1,K-1),R(I,J,K-1),DYM1,DYJ)*V(I,J ,K-1)

```

```

GF =SILIN(R(I,J,K+1),R(I,J,K ),DZFF,DZF)*W(I,J,K+1)
GP =SILIN(R(I,J,K-1),R(I,J,K ),DZB ,DZF)*W(I,J,K )
GB =SILIN(R(I,J,K-2),R(I,J,K-1),DZBB,DZB)*W(I,J,K-1)

```

```

GEF=SILIN(R(I+1,J,K ),R(I,J,K ),DXP1,DXI)*U(I+1,J,K )
GEB=SILIN(R(I+1,J,K-1),R(I,J,K-1),DXP1,DXI)*U(I+1,J,K-1)
GWF=SILIN(R(I-1,J,K ),R(I,J,K ),DXM1,DXI)*U(I ,J,K )
GWB=SILIN(R(I-1,J,K-1),R(I,J,K-1),DXM1,DXI)*U(I ,J,K-1)

```

```

C **** MASS FLOW RATE

```

```

CN=SILIN(GNF,GNB,DZF,DZB)*DZXN
CS=SILIN(GSF,GSB,DZF,DZB)*DZXS
CE=SILIN(GEF,GEB,DZF,DZB)*DYZE
CW=SILIN(GWF,GWB,DZF,DZB)*DYZW
CF=0.5*(GF+GP)*DXYF
CB=0.5*(GP+GB)*DXYB

```

```

C **** VISCOSITY

```

```

VISF=VIS(I,J,K )
VISB=VIS(I,J,K-1)
VISN=(VIS(I,J+1,K)+VIS(I,J,K)+VIS(I,J+1,K-1)+VIS(I,J,K-1))/4.
VISS=(VIS(I,J-1,K)+VIS(I,J,K)+VIS(I,J-1,K-1)+VIS(I,J,K-1))/4.
VISE=(VIS(I+1,J,K)+VIS(I,J,K)+VIS(I+1,J,K-1)+VIS(I,J,K-1))/4.
VISW=(VIS(I-1,J,K)+VIS(I,J,K)+VIS(I-1,J,K-1)+VIS(I,J,K-1))/4.

```

```

VISN1=ZXOYN*VISN
VISS1=ZXOYS*VISS
VISE1=YZOXE*VISE
VISW1=YZOXW*VISW
VISF1=XYOZF*VISF
VISB1=XYOZB*VISB

```

```

C **** QUICK SCHEME

```

```

CEP=(ABS(CE)+CE)*DXP1*DXI/(8.*DXE*(DXE+DXW ))
CEM=(ABS(CE)-CE)*DXP1*DXI/(8.*DXE*(DXE+DXEE))
CWP=(ABS(CW)+CW)*DXM1*DXI/(8.*DXW*(DXW+DXWW))
CWM=(ABS(CW)-CW)*DXM1*DXI/(8.*DXW*(DXW+DXE ))

CNP=(ABS(CN)+CN)*DYP1*DYJ/(8.*DYN*(DYN+DYS ))
CNM=(ABS(CN)-CN)*DYP1*DYJ/(8.*DYN*(DYN+DYNN))
CSP=(ABS(CS)+CS)*DYM1*DYJ/(8.*DYS*(DYS+DYSS))
CSM=(ABS(CS)-CS)*DYM1*DYJ/(8.*DYS*(DYS+DYN ))

CFP=(ABS(CF)+CF)*DZF/(DZK *16.)

```

```

CFM=(ABS(CF)-CF)*DZF/(DZP1*16.)
CBP=(ABS(CB)+CB)*DZB/(DZM1*16.)
CBM=(ABS(CB)-CB)*DZB/(DZK *16.)

AE(I,J,K)=(-.5*CE*DXI+CWM*DXW)/DXE+CEP+CEM*(1.+DXE/DXEE)+VISE1
AW(I,J,K)=(-.5*CW*DXI+CEP*DXE)/DXW+CWM+CWP*(1.+DXW/DXWW)+VISW1
AN(I,J,K)=(-.5*CN*DYJ+CSM*DYS)/DYN+CNP+CNM*(1.+DYN/DYNN)+VISN1
AS(I,J,K)=(-.5*CS*DYZ+CSM*DYN)/DYS+CSM+CSP*(1.+DYS/DYSS)+VISS1
AF(I,J,K)=-.5*CF      +CBM*DZB /DZF+CFP+CFM*(1.+DZF/DZFF)+VISF1
AB(I,J,K)=.5*CB      +CFP*DZF /DZB+CBM+CBP*(1.+DZB/DZBB)+VISB1

C *** BOUNDARY CONSIDERATION
IF (I.LT.NI+3) THEN
  AEE=-CEM*DXE/DXEE
  AEER=AEE*WPD(I+2,J,K)
ELSE
  AEE=0.
  AEER=0.
ENDIF

IF (I.GT.2) THEN
  AWW=-CWP*DXW/DXWW
  AWWR=AWW*WPD(I-2,J,K)
ELSE
  AWW=0.
  AWWR=0.
ENDIF

IF (J.LT.NJ+3) THEN
  ANN=-CNM*DYN/DYNN
  ANNR=ANN*WPD(I,J+2,K)
ELSE
  ANN=0.
  ANNR=0.
ENDIF

IF (J.GT.2) THEN
  ASS=-CSP*DYS/DYSS
  ASSR=ASS*WPD(I,J-2,K)
ELSE
  ASS=0.
  ASSR=0.
ENDIF

IF (K.LT.NK+3) THEN
  AFF=-CFM*DZF/DZFF
  AFFR=AFF*WPD(I,J,K+2)
ELSE
  AFF=0.
  AFFR=0.
ENDIF

IF (K.GT.3) THEN
  ABB=-CBP*DZB/DZBB
  ABBR=ABB*WPD(I,J,K-2)
ELSE

```

```

ABB=0.
ABBR=0.
ENDIF

C *** MODIFICATION FOR DECK BOUNDARIES
IF (NOD(I-1,J,K).NE.0) THEN
  AWW=0.0
  AWWR=0.0
ENDIF

IF (NOD(I+1,J,K).NE.0) THEN
  AEE=0.0
  AEER=0.0
ENDIF

IF (NOD(I,J-1,K).NE.0) THEN
  ASS=0.0
  ASSR=0.0
ENDIF

IF (NOD(I,J+1,K).NE.0) THEN
  ANN=0.0
  ANNR=0.0
ENDIF

IF (NOD(I,J,K-2).NE.0) THEN
  ABB=0.0
  ABBR=0.0
ENDIF

IF (NOD(I,J,K+1).NE.0) THEN
  AFF=0.0
  AFFR=0.0
ENDIF

C *** SU FROM NORMAL STRESS
RF=(SIG33(I,J,K )-(W(I,J,K+1)-W(I,J,K ))*VISF/DZF)*DXYF
RB=(SIG33(I,J,K-1)-(W(I,J,K )-W(I,J,K-1))*VISB/DZB)*DXYB
RN=(SIG23(I,J+1,K )-(W(I,J+1,K )-W(I,J ,K ))*VISN/DYN)*DZNX
RS=(SIG23(I,J ,K )-(W(I,J ,K )-W(I,J-1,K ))*VISS/DYS)*DZXS
RE=(SIG13(I+1,J,K )-(W(I+1,J,K )-W(I ,J,K ))*VISE/DXE)*DYZE
RW=(SIG13(I ,J,K )-(W(I ,J,K )-W(I-1,J,K ))*VISW/DXW)*DYZW

C *** SU FROM CURVED STRESSES AND ACCELERATIONS
AVG23= 0.5*(SIG23(I ,J+1,K )+SIG23(I ,J ,K ))
AVG13= 0.5*(SIG13(I+1,J ,K )+SIG13(I ,J ,K ))
AVG22=SILIN(SIG22(I,J,K ),SIG22(I,J,K-1),DZF,DZB)
AVG11=SILIN(SIG11(I,J,K ),SIG11(I,J,K-1),DZF,DZB)

AU3=W(I,J,K )
AU2=BILIN(V(I,J+1,K ),V(I,J,K ),DYJ,DYJ,
&           V(I,J+1,K-1),V(I,J,K-1),DYJ,DYJ,DZF,DZB)
&           AU1=BILIN(U(I+1,J,K ),U(I,J,K ),DXI,DXI,
&           U(I+1,J,K-1),U(I,J,K-1),DXI,DXI,DZF,DZB)

AR=SILIN(R(I,J,K ),R(I,J,K-1),DZF,DZB)

```

```

ARU23=AR*AU2*AU3
ARU13=AR*AU1*AU3
ARU22=AR*AU2*AU2
ARU11=AR*AU1*AU1

```

```

RRY=(AVG23-ARU23)*DXI*(DZN-DZS)
RRX=(AVG13-ARU13)*DYJ*(DZE-DZW)
RRZ=(AVG22-ARU22)*DXI*(DYF-DYB)+(AVG11-ARU11)*DYJ*(DXF-DXB)

```

```

AP(I,J,K)=AE(I,J,K)+AW(I,J,K)+AN(I,J,K)+AS(I,J,K)
& +AF(I,J,K)+AB(I,J,K)+AEE+AWW+ANN+ASS+AFF+ABB
SP(I,J,K)=-(ROD(I,J,K)*DZB+ROD(I,J,K-1)*DZF)*VOLDT/(DZB+DZF)
& SU(I,J,K)=-SP(I,J,K)*WOD(I,J,K)+DXI*DYJ*(P(I,J,K-1)-P(I,J,K))+AEER+AWWR+ANNR+ASSR+AFFR+ABBR+RE-RW+RN-RS+RF-RB+RRY+RRX-RRZ-BUOY*((R(I,J,K)-REQ(I,J,K))*DZB+(R(I,J,K-1)-REQ(I,J,K-1))*DZF)*VOL/(DZB+DZF)
&
&
&
100  CONTINUE

```

C \*\*\*\* TAKE CARE OF B.C. THRU AN,AS,AE,AW,AP AND SU

C \*\*\*\* Y DIRECTION

```

DO 500 K=3,NK+3
DO 500 I=2,NI+3
  SP(I,2      ,K)=SP(I,2      ,K)-AS(I,2      ,K)
  SP(I,NJ+3,K)=SP(I,NJ+3,K)-AN(I,NJ+3,K)
  AS(I,2      ,K)=0.
  AN(I,NJ+3,K)=0.

```

500 CONTINUE

C \*\*\*\* X DIRECTION

```

DO 502 K=3,NK+3
DO 502 J=2,NJ+3
  SP(2      ,J,K)=SP(2      ,J,K)-AW(2      ,J,K)
  SP(NI+3,J,K)=SP(NI+3,J,K)-AE(NI+3,J,K)
  AW(2      ,J,K)=0.0
  AE(NI+3,J,K)=0.0

```

502 CONTINUE

C \*\*\*\* Z DIRECTION

```

DO 600 I=2,NI+3
DO 600 J=2,NJ+3
  AF(I,J,NK+3)=0.
  AB(I,J,3      )=0.

```

600 CONTINUE

C \*\*\*\* MODIFICATION FOR DECK BOUNDARIES

```

IF (NCHIP.EQ.0) GOTO 201
DO 101 N=1,NCHIP
  IB  =ICHBP(N)
  IE  =IB+NCHPI(N)-1
  JB  =JCHPB(N)
  JE  =JB+NCHPJ(N)-1
  KB  =KCHPB(N)
  KE  =KB+NCHPK(N)-1

```

```

DO 102 J=JB,JE-1
DO 102 K=KB,KE
  SP(IB-1,J,K)=SP(IB-1,J,K)-AE(IB-1,J,K)
  SP(IE ,J,K)=SP(IE ,J,K)-AW(IE ,J,K)
  SU(IB-1,J,K)=SU(IB-1,J,K)+AE(IB-1,J,K)*WFAN(N)*2.0
  SU(IE ,J,K)=SU(IE ,J,K)+AW(IE ,J,K)*WFAN(N)*2.0
  AE(IB-1,J,K)=0.0
  AW(IE ,J,K)=0.0
102  CONTINUE

DO 103 I=IB,IE-1
DO 103 K=KB,KE
  SP(I,JB-1,K)=SP(I,JB-1,K)-AN(I,JB-1,K)
  SP(I,JE ,K)=SP(I,JE ,K)-AS(I,JE ,K)
  SU(I,JB-1,K)=SU(I,JB-1,K)+AN(I,JB-1,K)*WFAN(N)*2.0
  SU(I,JE ,K)=SU(I,JE ,K)+AS(I,JE ,K)*WFAN(N)*2.0
  AN(I,JB-1,K)=0.0
  AS(I,JE ,K)=0.0
103  CONTINUE

DO 106 I=IB,IE-1
DO 106 J=JB,JE-1
  SU(I,J,KB-1)=SU(I,J,KB-1)+AF(I,J,KB-1)*WFAN(N)
  SU(I,J,KE+1)=SU(I,J,KE+1)+AB(I,J,KE+1)*WFAN(N)
  AF(I,J,KB-1)=0.0
  AB(I,J,KE+1)=0.0
106  CONTINUE

C *** FOR THE CELLS INSIDE OF THE DECKS
DO 104 I=IB,IE-1
DO 104 J=JB,JE-1
DO 104 K=KB,KE
  SP(I,J,K)=-1.0E2
  AW(I,J,K)=0.
  AE(I,J,K)=0.
  AS(I,J,K)=0.
  AN(I,J,K)=0.
  AB(I,J,K)=0.
  AF(I,J,K)=0.
  SU(I,J,K)=1.0E2*WFAN(N)
104  CONTINUE
101  CONTINUE

C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS
201 DO 301 K=3,NK+3
  DO 301 J=2,NJ+3
  DO 301 I=2,NI+3
    DXI=DXXC(I)
    DYJ=DYYC(J)
    DXY=DXI*DYJ
    AP(I,J,K)=AP(I,J,K)-SP(I,J,K)
    DW(I,J,K)=DXY/AP(I,J,K)
301  CONTINUE

C *** SOLVE FOR W
  CALL TRID (3,3,4,NI+2,NJ+2,NK+2,W)

```

```

C **** RESET THE VELOCITY INSIDE OF THE DECKS
IF (NCHIP.EQ.0) GOTO 111
DO 110 N=1,NCHIP
  IB=ICHPB(N)
  IE=IB+NCHPI(N)-1
  JB=JCHPB(N)
  JE=JB+NCHPJ(N)-1
  KB=KCHPB(N)
  KE=KB+NCHPK(N)-1
  DO 108 I=IB,IE-1
  DO 108 J=JB,JE-1
  DO 108 K=KB,KE
    W(I,J,K)=WFAN(N)
108   CONTINUE
110 CONTINUE

111 RETURN
END

```

```

*****
***** SUBROUTINE GLOBE ****
***** THIS SUBROUTINE CALCULATES THE GLOBAL PRESSURE CORRECTION, WHEREBY THE
***** PRESSURE MATRIX IS UPDATED.
*  

*VARIABLES USED ARE:
* SUMT = SUM OF TEMPERATURES
* SUMPT = SUM OF PRESSURE OVER TEMPERATURE
* SUMPET = SUM OF EQUILIBRIUM PRESSURE OVER TEMP
* UGRT = CONSTANT (FROM SUBROUTINE INIT)
* PCORR = PRESSURE CORRECTION
*****
```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&           DYYC(40),DZZC(40),DXXS(40),DYYs(40),DZZS(40)
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,COND0,VISO,RHO0,
&           TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&           U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
&           SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
&           DV(25,25,15),DW(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&           CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)
```

```

SUMT=0.
SUMPT=0.
SUMPET=0.
DO 370 I=3,NI+2
DO 370 J=3,NJ+2
DO 370 K=3,NK+2
  IF (NOD(I,J,K).NE.1) THEN
```

```

DXI      = DXXC(I)
DYJ      = DYYC(J)
DZK      = DZZC(K)
VOL      = DXI*DYJ*DZK
SUMT    = SUMT+VOL/T(I,J,K)
SUMPT   = SUMPT+P(I,J,K)*VOL/T(I,J,K)
SUMPET  = SUMPET+REQ(I,J,K)*VOL*(1.-1./T(I,J,K))
ENDIF
370 CONTINUE
SUMPET = SUMPET/UGRT
PCORR  = (SUMPET-SUMPT)/SUMT

DO 371 I=1,NI+4
DO 371 J=1,NJ+4
DO 371 K=1,NK+4
    P(I,J,K) = P(I,J,K)+PCORR
371 CONTINUE

RETURN
END

```

```
*****
***** SUBROUTINE GRID *****
***** NONDIMENSIONAL VARIABLES:
* GRID SIZES:
*   DX = X DIRECTION
*   DY = Y DIRECTION
*   DZ = Z DIRECTION
*
* CENTRAL CELLS:
*   XC() = X COORDINATE
*   YC() = Y COORDINATE
*   ZC() = Z COORDINATE
*   DXXC() = X LENGTH
*   DYJC() = Y LENGTH
*   DZZC() = Z LENGTH
*
* STAGGERED CELLS:
*   XS() = X COORDINATE
*   YS() = Y COORDINATE
*   ZS() = Z COORDINATE
*   DXXS() = X LENGTH
*   DYYS() = Y LENGTH
*   DZZS() = Z LENGTH
*
```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
& DYYC(40),DZZC(40),DXXS(40),DYYS(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL2/X,Y,H,TFLR,TWAL
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP

```

```

C *** GENERATION OF THE GRIDS
DX=X/(DFLOAT(NI)*H)
DY=Y/(DFLOAT(NJ)*H)
DZ=H/(DFLOAT(NK)*H)

C *** CALCULATE XS,YS,ZS (COORDINATES OF STAGGERED CV'S)
DO 10 I=3,NI+3
    XS(I)=(I-3)*DX
10 CONTINUE
    XS(2)=XS(3)-TWAL/(H*12.)
    XS(1)=XS(2)-TWAL/(H*12.)
    XS(NI+4)=XS(NI+3)+TWAL/(H*12.)
    XS(NI+5)=XS(NI+4)+TWAL/(H*12.)

    DO 12 J=3,NJ+3
        YS(J)=(J-3)*DY
12 CONTINUE
    YS(2)=YS(3)-TWAL/(H*12.)
    YS(1)=YS(2)-TWAL/(H*12.)
    YS(NJ+4)=YS(NJ+3)+TWAL/(H*12.)
    YS(NJ+5)=YS(NJ+4)+TWAL/(H*12.)

    DO 14 K=3,NK+3
        ZS(K)=(K-3)*DZ
14 CONTINUE
    ZS(2)=ZS(3)-TFLR/(H*12.)
    ZS(1)=ZS(2)-TFLR/(H*12.)
    ZS(NK+4)=ZS(NK+3)+TFLR/(H*12.)
    ZS(NK+5)=ZS(NK+4)+TFLR/(H*12.)

C *** CALCULATE DXXC,DYYC AND DZZC (DIMENSIONS OF CENTERED CV'S)
DO 20 I=1,NI+4
    DXXC(I)=XS(I+1)-XS(I)
20 CONTINUE
    DXXC(NI+5)=DXXC(NI+4)

    DO 22 J=1,NJ+4
        DYYC(J)=YS(J+1)-YS(J)
22 CONTINUE
    DYYC(NJ+5)=DYYC(NJ+4)

    DO 24 K=1,NK+4
        DZZC(K)=ZS(K+1)-ZS(K)
24 CONTINUE
    DZZC(NK+5)=DZZC(NK+4)

C *** CALCULATE DXXS,DYYS,DZZS (DIMENSIONS OF STAGGERED CV'S)
DO 30 I=2,NI+5
    DXXS(I)=(DXXC(I)+DXXC(I-1))/2.0
30 CONTINUE
    DXXS(1)=DXXS(2)

    DO 32 J=2,NJ+5
        DYYs(J)=(DYYC(J)+DYYC(J-1))/2.0
32 CONTINUE
    DYYs(1)=DYYs(2)

```

```

DO 34 K=2,NK+5
  DZZS(K)=(DZZC(K)+DZZC(K-1))/2.0
34 CONTINUE
  DZZS(1)=DZZS(2)

C **** CALCULATE XC,YC,ZC (LOCATION OF CENTER CELLS)
  DO 40 I=1,NI+5
    XC(I)=XS(I)+DXXC(I)/2.0
 40 CONTINUE

  DO 42 J=1,NJ+5
    YC(J)=YS(J)+DYYC(J)/2.0
 42 CONTINUE

  DO 44 K=1,NK+5
    ZC(K)=ZS(K)+DZZC(K)/2.0
 44 CONTINUE

  RETURN
END

```

```

*****
***** SUBROUTINE INIT *****
***** THIS SUBROUTINE INITIALIZES THE FIELD AND CONSTANTS WITH RESPECT
***** TO INITIAL START OR RESTARTING CAPABILITY.
*  

*VARIABLES ARE :
* ALEW      = LEWIS NUMBER (USED IN SMOKE CONCENTRATION CALCULATIONS)
* BUOY      = BUOYANCY FORCE CONSTANT
* CO        = INITIAL SMOKE CONCENTRATION
* CONDO     = REFERENCE CONDUCTIVITY
* CONSRA    = NONDIMENSIONAL RADIATION CONSTANT
* CPO       = REFERENCE SPECIFIC HEAT
* F         = INITIAL MASS OF FUEL (LBM)
* FR        = MASS OF FUEL REMAINING (LBM)
* GC        = GRAVITY CONSTANT
* H         = CHARACTERISTIC LENGTH; HEIGHT OF CHAMBER=10.FT
* HCOEF     = DIMENSIONLESS HEAT TRANSFER COEF
* HCONV     = HEAT TRANSFER COEFFICIENT IN BTU/(HR*FT**2*DEGREES)
* HR        = HEIGHT IN CM
* NTAPE     = NONDIMENSIONAL FORMS OF TTAPE
* NWRITE    = NONDIMENSIONAL FORMS OF TWRITE
* RHOO      = REFERENCE DENSITY
* TA        = TEMP IN DEGREES RANKINE
* TIME      = DIMENSIONLESS TIME
* TR        = TEMP IN DEGREES KELVIN
* UO        = CHARACTERISTIC VELOCITY (1 FT/SEC)
* UGRT      = PERFECT GAS LAW NONDIMENSIONAL CONSTANT
* VISO      = REFERENCE VISCOSITY (NONDIM)
* VISL      = MINIMUM VISCOSITY (NONDIM)
* VISMAX    = MAXIMUM VISCOSITY (NONDIM)
*  

*MATRICES OF THE FORM

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* _OD      = DIMENSIONLESS PARAMETER AT PREVIOUS TIME STEP
* _          = DIMENSIONLESS PARAMETER AT CURRENT TIME STEP
* _PD      = DIMENSIONLESS PARAMETER AT NEXT TIME STEP
*
*WHERE THE PARAMETERS ARE
* AP       = COEFICIENT AT NODE P
* AE ,AW,AN = COEFICIENTS AT PTS EAST,WEST,NORTH,
* AS,AF,AB  SOUTH, FRONT, AND BACK
* CPM      = MEAN SPECIFIC HEAT
* COND( )  = CONDUCTIVITY MATRIX
* CX,CY,CZ = LOCATION OF THERMOCOUPLE IN X,Y,Z
* DU,DV,DW = USED IN PRESSURE CORRECTION SUBROUTINE
* DXXC,DYYC = LENGTH AROUND THE CENTER CELL
* DZZC
* DXXS,DYYS = LENGTH AROUND THE STAGGERED CELL
* DZZS
* NOD      = IF EQUAL TO ZERO, LIQUID; IF EQUAL TO ONE, SOLID
* PP       = CORRECTED PRESSURE (P')
* REQ      = DENSITY AT EQUILIBRIUM
* SMP      = RESIDUAL MASS SUMMATION OF NODAL POINT
* SMPP     = LENGTH SCALE FOR TURBULENCE
* SP       = BOUNDARY CONDITION TERM AT NODE P
* SU       = SOURCE TERM
* T,P,C    = TEMP, PRESSURE, AND SMOKE CONCENTRATION
* U,V,W    = VELOCITY COMPONENTS IN X,Y,X DIRECTIONS
* VIS      = VISCOSITY
* _B,_E    = BEGINNING AND ENDING NODAL POINT FOR
*             THE SOLID IN I,J,K
* XC,YC,ZC = X,Y,Z LOCATION OF CENTER CELL NODAL POINT
* XS,YS,ZS = X,Y,Z LOCATION OF STAGGERED CELL NODAL POINT
*****

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IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&           DYYC(40),DZZC(40),DXXS(40),DYYS(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL2/X,Y,H,TFLR,TWAL
COMMON/BL3/F,FR,HSTART
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL12/NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER
COMMON/BL14/HCOEF,CNT,ABTURB,BTURB,VISL,VISMAX
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,COND0,VISO,RHO0,
&           TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL20/SIG11(25,25,15),SIG12(25,25,15),SIG22(25,25,15),
&           SIG13(25,25,15),SIG23(25,25,15),SIG33(25,25,15)
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
&           JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),
&           COD(25,25,15),UOD(25,25,15),VOD(25,25,15),
&           WOD(25,25,15)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&           U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL33/TPD(25,25,15),RPD(25,25,15),PPD(25,25,15),
&           CPD(25,25,15),UPD(25,25,15),VPD(25,25,15),
&           WPD(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),

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& SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
& DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
& AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
& SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
& CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)
COMMON/BL38/TCOUP(30),CX(30),CY(30),CZ(30),NTH(30,3),NTHCO
COMMON/BL39/ALEW,CONSRA,QSIN,QSWER,QSWAL,QSAIR,QSFAN
COMMON/BL43/QSCONF,QSCONB,QSCONE,QSCONW,QSCONN,QSCONS,
& QSRADF,QSRADB,QSRADE,QSRADW,QSRADN,QSRADS,
& WAIR,WWAL,WINS,WERR,WWFAN

C *** INITIALIZE GIVEN PARAMETERS
C0=0.0
F=200.0
HCONV=15.0
NBLOR=13
PI=4.*ATAN(1.)
TCOOL=1.0

C *** nondimensionalize the reference viscosity
VIS0=VISO/(U0*H)
VISL=VISO

C *** set maximum viscosity
VISMAX=400.*VISL

C *** nondimensionalize the heat transfer coefficient
HCOEF=HCONV/(3600.*CPO*RHO0*U0)

CONDO=VISO/PRT
FR=F
BUOY=GC*H/(U0**2)
UGRT=U0**2/(GC*RAIR*TA)
CONSRA=1.714E-9*TA**3/(RHO0*CPO*U0*3600.)

C *** for energy distribution
QSIN=0.
QSINR=0.
QSWAL=0.
QSAIR=0.
QSFAIR=0.

C *** initialize conduction heat flux to each wall
QSCONF=0.
QSCONB=0.
QSCONE=0.
QSCONW=0.
QSCONN=0.
QSCONS=0.

C *** initialize radiation heat flux to each wall
QSRADF=0.
QSRADB=0.
QSRADE=0.

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```

QSRADW=0.
QSRADN=0.
QSRADS=0.

NWRITE=TWRITE*U0/(DTIME*H)
NTAPE=TTAPE*U0/(DTIME*H)

C *** INITIALIZE VARIABLE FIELDS
DO 220 J=1,NJ+4
DO 220 I=1,NI+4
DO 220 K=1,NK+4

  IF(KRUN.LE.0) THEN
    UOD(I,J,K) =0.
    VOD(I,J,K) =0.
    WOD(I,J,K) =0.
    POD(I,J,K) =0.
    TOD(I,J,K) =TA/TA
    COD(I,J,K) =C0
  ENDIF

  U(I,J,K) =UOD(I,J,K)
  UPD(I,J,K) =UOD(I,J,K)

  V(I,J,K) =VOD(I,J,K)
  VPD(I,J,K) =VOD(I,J,K)

  W(I,J,K) =WOD(I,J,K)
  WPD(I,J,K) =WOD(I,J,K)

  P(I,J,K) =POD(I,J,K)
  PPD(I,J,K) =POD(I,J,K)

  T(I,J,K) =TOD(I,J,K)
  TPD(I,J,K) =TOD(I,J,K)

  C(I,J,K) =COD(I,J,K)
  CPD(I,J,K) =COD(I,J,K)

  DU(I,J,K) =0.
  DV(I,J,K) =0.
  DW(I,J,K) =0.

  SU(I,J,K) =0.
  SP(I,J,K) =0.

  PP(I,J,K) =0.

  AP(I,J,K) =0.
  AW(I,J,K) =0.
  AE(I,J,K) =0.
  AN(I,J,K) =0.
  AS(I,J,K) =0.
  AF(I,J,K) =0.
  AB(I,J,K) =0.

```

```

SMP(I,J,K) =0.
SMPP(I,J,K) =0.

SIG11(I,J,K)=0.
SIG12(I,J,K)=0.
SIG13(I,J,K)=0.
SIG22(I,J,K)=0.
SIG23(I,J,K)=0.
SIG33(I,J,K)=0.

VIS(I,J,K) =VISL
COND(I,J,K) =COND0
CPM(I,J,K) =1.0E0
NOD(I,J,K) =0
220 CONTINUE

C **** DEFINE THERMAL PROPERTIES OF DECK AND SOLID
C      IF (NCHIP.NE.0) CALL SOLCON

C **** DEFINE HEIGHT OF NODE POINTS AND COMPUTE HYDROSTATIC
C      EQUILIBRIUM DENSITY REQ(I,J,K)
15 DO 229 J=1,NJ+4
    DO 229 I=1,NI+4
    DO 229 K=1,NK+4
        HEIGHT(I,J,K)=ZC(K)
        REQ(I,J,K) =EXP(-BUOY*UGRT*HEIGHT(I,J,K))
        IF(KRUN.LE.0) THEN
            ROD(I,J,K)=REQ(I,J,K)/TPD(I,J,K)
        ENDIF
        R(I,J,K) =ROD(I,J,K)
        RPD(I,J,K)=ROD(I,J,K)
229 CONTINUE

C **** FOLLOWING IS FOR DETERMINING THE THERMOCOUPLE POSITIONS
DO 5000 N=1,NTHCO
    DO 5001 I=1,NI+4
        IF (XC(I).LT.CX(N).AND.XC(I+1).GE.CX(N)) GOTO 5002
5001 CONTINUE

5002 II=I
    DO 5003 J=1,NJ+4
        IF (YC(J).LT.CY(N).AND.YC(J+1).GE.CY(N)) GOTO 5004
5003 CONTINUE

5004 JJ=J
    DO 5005 K=1,NK+4
        IF (ZC(K).LT.CZ(N).AND.ZC(K+1).GE.CZ(N)) GOTO 5006
5005 CONTINUE

5006 KK=K
    NTH(N,1)=II
    NTH(N,2)=JJ
    NTH(N,3)=KK
5000 CONTINUE

RETURN

```

END

```
*****
***** SUBROUTINE INPUT(NSTOP)
***** THIS SUBROUTINE SETS UP REQUIRED VALUES TO BEGIN THE PROGRAM.
*
*VARIABLES ARE:
* KRUN      = RESTART INDICATOR
* NCHIP      = NUMBER OF INTERNAL SOLID PIECES
* NMS       = NUMBER OF MASS SOURCES
* NWRP      = NUMBER OF TIME STEPS BETWEEN WRITES TO OUTPUT FILE
* NTHCO     = NUMBER OF THERMOCOUPLES TO PRINT OUT
* TMAX      = NONDIMENSIONAL MAXIMUM TIME ALLOWED
* XTMAX     = MAXIMUM TIME ALLOWED (SECONDS)
* TWRITE    = TIME BETWEEN FIELD VARIABLE OUTPUT (SECONDS)
* TTAPE     = TIME INTERVAL BETWEEN PLOTS (SECONDS)
* DTIME     = NONDIMENSIONAL TIME STEP
* XDTIME    = TIME STEP (SECONDS)
* HSTART    = FIRE START TIME (SECONDS)
* NHSZ(1,1) = STARTING NODE OF HEAT SOURCE, X-DIR
* NHSZ(2,1) =                               Y-DIR
* NHSZ(3,1) =                               Z-DIR
* NHSZ(1,2) = ENDING NODE OF HEAT SOURCE, X-DIR
* NHSZ(2,2) =                               Y-DIR
* NHSZ(3,2) =                               Z-DIR
* ICHPB     = FIRST NODE OF INTERNAL SOLID IN X DIR
* JCHPB     =                               Y DIR
* KCHPB     =                               Z DIR
* NCHPI     = NUMBER OF INTERNAL SOLID NODES IN X DIR
* NCHPJ     =                               Y DIR
* NCHPK     =                               Z DIR
* IMSB      = FIRST MASS SOURCE NODE IN X DIR
* JMSB      =                               Y DIR
* KMSB      =                               Z DIR
* NMSI      = NUMBER OF MASS SOURCE NODES IN X DIR
* NMSJ      =                               Y DIR
* NMSK      =                               Z DIR
* RMS       = DIMENSIONLESS MASS SOURCE
*           (= CFM/(60.*H**2*U0*NMSI*NMSJ*NMSK))
* CX,CY,CZ = THERMOCOUPLE POSITIONS IN X,Y,Z
*****
*DATA FILES USED IN THIS PROGRAM:
*
* FILE # 10 = FIRE.DAT : INITIAL SET-UP DATA
*           11 = FIRE1.CONT : RESTART/CONTINUATION DATA
*
*****
```

```
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL2/X,Y,H,TFLR,TWAL
COMMON/BL3/F,FR,HSTART
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL12/NWRITE,NTAPE,NTMAXO,NTREAL,TIME,SORSUM,ITER
```

```

COMMON/BL16/U0 ,UGRT,BUOY,CPO,PRT,CONDO,VISO,RHOO ,
& TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
& JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL23/RMS(20),NMS,IMSB(20),NMSI(20),JMSB(20),NMSJ(20),
& KMSB(20),NMSK(20)
COMMON/BL31/TOD(25,25,15),ROD(25,25,15),POD(25,25,15),
& COD(25,25,15),UOD(25,25,15),VOD(25,25,15),
& WOD(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
& CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)
COMMON/BL38/TCOUP(30),CX(30),CY(30),CZ(30),NTH(30,3),NTHCO

CHARACTER ANS*1
LOGICAL L1,L2
NSTOP=0
KRUN=0

***** CHECK FOR INPUT DATA FILE
INQUIRE (FILE='/FIRE DATA B1',EXIST=L1)
IF (L1) THEN

C *** READ IN DATA FROM EXISTING DATA FILE
OPEN(10,FILE='/FIRE DATA B1',STATUS='OLD')
REWIND(10)
READ(10,*) X,Y,H,TFLR,TWAL,TA
READ(10,*) NI,NJ,NK
READ(10,*) NCHIP,NMS,NWRP,NTHCO
READ(10,*) TMAX,DTIME,TTAPE,TWRITE,HSTART
READ(10,*) NHSZ(1,1),NHSZ(1,2),NHSZ(2,1),NHSZ(2,2),NHSZ(3,1),
& NHSZ(3,2)
IF (NCHIP.LE.0) GOTO 33
DO 32 N=1,NCHIP
    READ(10,*) ICHPB(N),NCHPI(N),JCHPB(N),NCHPJ(N),KCHPB(N),
    & NCHPK(N),CPS(N),CONS(N),WFAN(N)
32  CONTINUE
33  IF (NMS.LE.0) GOTO 37
DO 36 N=1,NMS
    READ(10,*) IMSB(N),NMSI(N),JMSB(N),NMSJ(N),KMSB(N),
    & NMSK(N),RMS(N)
36  CONTINUE
37  DO 38 I=1,NTHCO
    READ (10,*) CX(I),CY(I),CZ(I)
38  CONTINUE
REWIND(10)
CLOSE(10)
ELSE

C *** STOP PROGRAM IF INPUT DATA NOT AVAILABLE
NSTOP=9999
GOTO 999
ENDIF

***** CHECK FOR CONTINUATION FILE
INQUIRE (FILE='/CONTINUE DATA B4',EXIST=L2)
IF (L2) THEN

```

```

C *** READ IN DATA FROM OLD CONTINUATION FILE
      OPEN(11,FILE='/CONTINUE DATA B4',STATUS='OLD',
      &      FORM='UNFORMATTED')
      KRUN=1
      REWIND(11)
      READ(11) TIME,NTMAX0,FR,TOD,ROD,UOD,VOD,WOD,POD,COD
      REWIND(11)
      IF(TIME.GE.TMAX) TMAX=TIME+TMAX
      ELSE
      ENDIF

C *** CREATE NEW CONTINUATION FILE
      OPEN(11,FILE='/CONTINUE DATA B4',STATUS='NEW',
      &      FORM='UNFORMATTED')
      KRUN=0
      ENDIF

999 RETURN
END

```

```

*****
***** SUBROUTINE OUT(NN)
***** THIS SUBROUTINE GENERATES OUTPUT.
*
* NN = 1      SELECTED VALUES ARE PRINTED. INCLUDING TIME, ERROR,
*             PRESSURE, HEAT GENERATION
* NN = 2      TEMPERATURE AT THE THERMOCOUPLES
* NN = 3      FILED VALUES ARE PRINTED
* NN = 4      ENERGY DISTRIBUTION
*****
```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL2/X,Y,H,TFLR,TWAL
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL12/NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,COND0,VISO,RHO0,
&      TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&      U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL34/HEIGHT(25,25,15),REQ(25,25,15),SMP(25,25,15),
&      SMPP(25,25,15),PP(25,25,15),DU(25,25,15),
&      DV(25,25,15),DW(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
&      AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
&      SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&      CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)
COMMON/BL38/TCOUP(30),CX(30),CY(30),CZ(30),NTH(30,3),NTHCO
COMMON/BL39/ALEW,CONSRA,QSIN,QSWER,QSWAL,QSAIR,QSFAN
COMMON/BL43/QSCONF,QSCONB,QSCONE,QSCONW,QSCONN,QSCONS,QSRADF,
&      QSRADB,QSRADE,QSRADW,QSRADN,QSRADS,WAIR,WWAL,WINS,
&      WERR,WWFAN

```

```
*****
500 FORMAT(1X,'TIME=' ,F7.3, ' SECONDS' ,2X,'NTREAL=' ,I5,2X,'ITER=' ,I5,
& 2X,'SOURCE=' ,F9.6,2X,'SORSUM=' ,F9.6,2X,' Q(KW) = ' ,F10.4)
504 FORMAT(/,1X,'J=' ,I2,5X,'K=' ,I2,/,10X,'T (C)' ,
& 4X,'U(CM/SEC)' ,2X,'V(CM/SEC)' ,2X,'W(CM/SEC)' ,/)
511 FORMAT(1X,'I=' ,I3,2X,F9.4,2X,F9.4,2X,F9.4,2X,F9.4)
1084 FORMAT(6X,'*** AT TIME = ' ,F9.4,' ***',/,,
& 9X,'THE WATTAGE INPUT: WINS = ' ,E10.4,/,,
& 9X,'WATTAGE INTO AIR: WAIR = ' ,E10.4,/,,
& 9X,'WATTAGE DUE TO ERRO = ' ,E10.4,/,,
& 9X,'WATTAGE THRU DUCT: WAIR = ' ,E10.4,/,,
& 9X,'INTO THE WALL: WWAL = ' ,E10.4,
& 2X,'BY CONDUCTION: QTCON = ' ,E10.4,
& 2X,'BY RADIATION: QTRAD = ' ,E10.4,/)
2728 FORMAT(9X,'QSRADW: INTO WEST WALL BY RADIATION= ' ,E10.4,
& 9X,'QSCONW: BY CONDUCTION = ' ,E10.4,/,,
& 9X,'QSRADE: INTO EAST WALL BY RADIATION= ' ,E10.4,
& 9X,'QScone: BY CONDUCTION = ' ,E10.4,/,,
& 9X,'QSRADS: INTO SOUTH WALL BY RADIATION= ' ,E10.4,
& 9X,'QSCONS: BY CONDUCTION = ' ,E10.4,/,,
& 9X,'QSRADN: INTO NORTH WALL BY RADIATION= ' ,E10.4,
& 9X,'QSCONN: BY CONDUCTION = ' ,E10.4,/,,
& 9X,'QSRADB: INTO BACK WALL BY RADIATION= ' ,E10.4,
& 9X,'QSCONB: BY CONDUCTION = ' ,E10.4,/,,
& 9X,'QSRADF: INTO FRONT WALL BY RADIATION= ' ,E10.4,
& 9X,'QSCONF: BY CONDUCTION = ' ,E10.4,/)
1088 FORMAT(9X,'PAIR : LOSS INTO CAVITY AIR = ' ,F8.3,' %',/,,
& 9X,'PWER : LOSS DUE TO THE ERR = ' ,F8.3,' %',/,,
& 9X,'PWALL: LOSS INTO THE WALLS = ' ,F8.3,' %',/,,
& 9X,'PFAN : LOSS THROUGH DUCT = ' ,F8.3,' %',/,,
& 9X,'PSAIR: TOTAL INTO CAVITY AIR = ' ,F8.3,' %',/,,
& 9X,'PSWER: TOTAL DUE TO THE ERRO = ' ,F8.3,' %',/,,
& 9X,'PSFAN: TOTAL THROUGH DUCT = ' ,F8.3,' %',/,,
& 9X,'PSWAL: TOTAL INTO THE WALLS = ' ,F8.3,' %',/)
1091 FORMAT(9X,'QSIN : TOTAL ENERGY INPUT = ' ,E10.4,/,,
& 9X,'QSWER : TOTAL ENERGY DUE TO THE ERRO= ' ,E10.4,/,,
& 9X,'QSAIR : TOTAL ENERGY INTO CAVITY AIR= ' ,E10.4,/,,
& 9X,'QSFAN : TOTAL ENERGY THROUGH DUCT = ' ,E10.4,/,,
& 9X,'QSWAL : TOTAL ENERGY INTO WALLS = ' ,E10.4,2X,/)
*****
```

C \*\*\* REFERENCE TEMPERATURE IN DEGREES K  
TR=TA/1.8

C \*\*\* REFERENCE VELOCITY IN CM/SEC  
UR=U0\*30.48

C \*\*\* REFERENCE LENGTH IN CM  
HR=H\*30.48

```
XTIME=TIME*H/U0
IF (NN.EQ.1) THEN
  QRR=60.**2*QR/3412.
  QKW=60.**2*Q /3412.
  WRITE(12,500) XTIME,NTREAL,ITER,RESORM(ITER),SORSUM,QKW
```

```

ELSE IF (NN.EQ.2) THEN
  WRITE (12,*)
  WRITE (12,*)' TEMPERATURES AT THERMOCOUPLE POSITION IN (C):',
&           (TCOUP(N)*TR-273.16,N=1,NTHCO)
  WRITE (12,*)
  WRITE (12,*)
ELSE IF (NN.EQ.3) THEN
  WRITE(12, '(1X,A,F10.6)') 'TIME =', XTIME
  DO 501 J=3,NJ+3,NJ
    DO 502 K=2,NK+4
      WRITE(12,504) J,K
513    DO 503 I=1,NI+4
      IF (T(I,J,K).LT.TCOOL) T(I,J,K)=TCOOL
      XTEMP=T(I,J,K)*TR-273.16
      XR =1000.*(0.0328)**3*R(I,J,K)*RHOO/2.2048
      XU =U(I,J,K)*UR
      XV =V(I,J,K)*UR
      XW =W(I,J,K)*UR
      XP =P(I,J,K)*RHOO*U0**2/(GC*14.696*144.)+REQ(I,J,K)
      XVIS =VIS(I,J,K)*HR*UR
      XCOND=COND(I,J,K)*HR*UR
      WRITE(12,511)I,XTEMP,XU,XV,XW
503    CONTINUE
502    CONTINUE
501    CONTINUE
  ELSE
C **** CALCULATE THE PERCENTAGE AND PRINT OUT THE RESULTS
  QTCON=QSCONF+QSCONB+QSCONS+QSCONN+QSCONW+QSCONE
  QTRAD=QSRADF+QSRADB+QSRADS+QSRADN+QSRADW+QSRADE
C **** WATT PERCENTAGE
  IF (WINS.EQ.0.) WINS=1.0E-5
  PAIR=100.*WAIR /WINS
  PWAL=100.*WWAL /WINS
  PFAN=100.*WWFAN/WINS
  PWER=100.*WERR /WINS
C **** ENERGY PERCENTAGE
  IF (QSIN.EQ.0.0) QSIN=1.0E-3
  PSAIR=100.*QSAIR/QSIN
  PSWAL=100.*QSWAL/QSIN
  PSFAN=100.*QSFAN/QSIN
  PSWER=100.*QSWER/QSIN
  WRITE(12,1084)XTIME,WINS,WAIR,WERR,WWFAN,WWAL,QTCON,QTRAD
  WRITE(12,2728)QSRADW,QSCONW,QSRADE,QSCONE,QSRADS,QSCONS,
&           QSRADN,QSCONN,QSRADB,QSCONB,QSRADF,QSCONF
  WRITE(12,1088)PAIR,PWER,PWAL,PFAN,PSAIR,PSWER,PSFAN,PSWAL
  WRITE(12,1091)QSIN,QSWER,QSAIR,QSFAN,QSWAL
ENDIF

RETURN
END
*****
*****
```

## SUBROUTINE RADHT (NN)

```
*****
* NN = CONTROL PARAMETER FOR HEAT FLUX CALCULATIONS
* WHERE NN=1 :CALCULATE HEAT FLUX FROM FIRE TO WALLS
* NN=2 :CALCULATE HEAT FLUX FROM FIRE TO BLOCKS
*
* NTHS      = TOTAL NUMBER OF CV'S CONTAINING HEAT SOURCES
* NFX,NFY,NFZ = CV NUMBER OF HEAT SOURCE
* FX,FY,FZ    = COORDINATES OF HEAT SOURCE
*****
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
& .      DYYC(40),DZZC(40),DXXS(40),DYYs(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
&      JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&      U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
&      AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
&      SU(25,25,15),RI(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&      CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)
COMMON/BL39/ALEW,CONSRA,QSIN,QSWER,QSWAL,QSAIR,QSFAN
COMMON/BL40/VFHSW(5,25,15),VFHSE(5,25,15),VFHSS(5,15,25),
&      VFHSN(5,15,25),VFHSB(5,25,25),VFHSF(5,25,25)
COMMON/BL41/VFHSBW(5,8,34,34),VFHSBE(5,8,34,34),VFHSBS(5,8,34,34),
&      VFHSBN(5,8,34,34),VFHSBB(5,8,34,34),VFHSBF(5,8,34,34)

NTHS=NHSZ(3,2)-NHSZ(3,1)+1
DO 500 N=1,NTHS
  NFX=NHSZ(1,1)
  NFY=NHSZ(2,1)
  NFZ=NHSZ(3,1)-1+N

C *** AREA OF THE FIRE ELEMENTS
  DYHS=DYYC(NFY)
  DZHS=DZZC(NFZ)
  DAHS=PI*DYHS*DZHS
  EMIS=0.6

C *** NN=1: CALCULATE RADIATION HEAT FLUX FROM FIRE TO WEST AND
C *** EAST SURFACES OF THE ENCLOSURE
  IF (NN.EQ.1) THEN
    DO 100 J=3,NJ+2
      DO 100 K=3,NK+2
        SU(2,J,K) =SU(2,J,K)+CONSRA*EMIS*DAHS*VFHSW(N,J,K)*
        &           (T(NFX,NFY,NFZ)**4-T(2,J,K)**4)
        SU(NI+3,J,K)=SU(NI+3,J,K)+CONSRA*EMIS*DAHS*VFHSE(N,J,K)*
        &           (T(NFX,NFY,NFZ)**4-T(NI+3,J,K)**4)
    100      CONTINUE

C *** CALCULATE RADIATION HEAT FLUX FROM FIRE TO NORTH AND
C *** SOUTH SURFACES OF THE ENCLOSURE
```

```

DO 200 I=3,NI+2
DO 200 K=3,NK+2
  SU(I,2,K) =SU(I,2,K)+CONSRA*EMIS*DAHS*VFHSS(N,K,I)*
  & (T(NFX,NFY,NFZ)**4-T(I,2,K)**4)
  & SU(I,NJ+3,K)=SU(I,NJ+3,K)+CONSRA*EMIS*DAHS*VFHSN(N,K,I)*
  & (T(NFX,NFY,NFZ)**4-T(I,NJ+3,K)**4)
200      CONTINUE

C *** CALCULATE RADIATION HEAT FLUX FROM FIRE TO BACK AND
C *** FRONT SURFACES OF THE ENCLOSURE
DO 300 I=3,NI+2
DO 300 J=3,NJ+2
  SU(I,J,2) =SU(I,J,2)+CONSRA*EMIS*DAHS*VFHSB(N,I,J)*
  & (T(NFX,NFY,NFZ)**4-T(I,J,2)**4)
  & SU(I,J,NK+3)=SU(I,J,NK+3)+CONSRA*EMIS*DAHS*VFHSF(N,I,J)*
  & (T(NFX,NFY,NFZ)**4-T(I,J,NK+3)**4)
300      CONTINUE
ENDIF

C *** NN=2:  CALCULATE RADIATION HEAT FLUX FROM FIRE TO WEST AND
C *** EAST SURFACES OF BLOCK M
IF (NN.EQ.2) THEN
  IF (NCHIP.LT.NBLOR) THEN
    DO 900 M=1,NCHIP-NBLOR+1
      IB=ICHPB(M+NBLOR-1)
      IE=IB+NCHPI(M+NBLOR-1)-1
      JB=JCHPB(M+NBLOR-1)
      JE=JB+NCHPJ(M+NBLOR-1)-1
      KB=KCHPB(M+NBLOR-1)
      KE=KB+NCHPK(M+NBLOR-1)-1

C *** CALCULATE RADIATION HEAT FLUX FROM FIRE TO WEST AND
C *** EAST SURFACES OF THE BLOCK
    DO 400 J=JB,JE-1
    DO 400 K=KB,KE-1
      SU(IB,J,K) =SU(IB,J,K)+CONSRA*EMIS*DAHS*
      & VFHSBW(N,M,J,K)*(T(NFX,NFY,NFZ)**4-
      & T(IB,J,K)**4)
      & SU(IE-1,J,K)=SU(IE-1,J,K)+CONSRA*EMIS*DAHS*
      & VFHSBE(N,M,J,K)*(T(NFX,NFY,NFZ)**4-
      & T(IE-1,J,K)**4)
400      CONTINUE

C *** CALCULATE RADIATION HEAT FLUX FROM FIRE TO NORTH AND
C *** SOUTH SURFACES OF THE BLOCK
    DO 600 I=IB,IE-1
    DO 600 K=KB,KE-1
      SU(I,JB,K) =SU(I,JB,K)+CONSRA*EMIS*DAHS*
      & VFHSBS(N,M,K,I)*(T(NFX,NFY,NFZ)**4-
      & T(I,JB,K)**4)
      & SU(I,JE-1,K)=SU(I,JE-1,K)+CONSRA*EMIS*DAHS*
      & VFHSBN(N,M,K,I)*(T(NFX,NFY,NFZ)**4-
      & T(I,JE-1,K)**4)
600      CONTINUE

```

```

C *** CALCULATE RADIATION HEAT FLUX FROM FIRE TO BACK AND
C *** FRONT SURFACES OF BLOCK
    DO 700 I=IB,IE-1
    DO 700 J=JB,JE-1
        SU(I,J,KB) = SU(I,J,KB)+CONSRA*EMIS*DAHS*
        &           VFHSBB(N,M,I,J)*(T(NFX,NFY,NFZ)**4-
        &           T(I,J,KB)**4)
        SU(I,J,KE-1)=SU(I,J,KE-1)+CONSRA*EMIS*DAHS*
        &           VFHSBF(N,M,I,J)*(T(NFX,NFY,NFZ)**4-
        &           T(I,J,KE-1)**4)
700          CONTINUE
900          CONTINUE
        ENDIF
    ENDIF
500 CONTINUE

    RETURN
END

```

```

*****
***** SUBROUTINE SOLCON *****
*****
*   THIS SUBROUTINE RESETS THE CONDUCTIVITY OF THE SOLID. IN CALVIS      *
*   THE VISCOSITY ARE CALCULATED AT EVERY CELL INCLUDING THOSE          *
*   CONTAINING SOLID ONES.                                              *
*****

```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL16/U0,UGRT,BUOY,CPO,PRT,COND0,VISO,RHO0,
&           TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR,NT
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHPB(20),NCHPI(20),
&           JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&           CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)

DO 402 N=1,NCHIP
    IB=ICHPB(N)
    IE=IB+NCHPI(N)-1
    JB=JCHPB(N)
    JE=JB+NCHPJ(N)-1
    KB=KCHPB(N)
    KE=KB+NCHPK(N)-1
    DO 405 I=IB,IE-1
    DO 405 J=JB,JE-1
    DO 405 K=KB,KE-1
        COND(I,J,K)=COND0*CONS(N)
        CPM(I,J,K)=CPS(N)
        NOD(I,J,K)=1

```

```

C *** SET VALUE AT CORNER OR BOUNDARIES FOR BOUNDARY CONDITIONS
    IF (I.EQ.2) THEN
        COND(1,J,K)=COND(2,J,K)
        CPM (1,J,K)=CPM (2,J,K)
    ELSEIF (I.EQ.NI+3) THEN

```

```

COND(NI+4,J,K)=COND(NI+3,J,K)
CPM (NI+4,J,K)=CPM (NI+3,J,K)
ENDIF

IF (J.EQ.2) THEN
  COND(I,1,K)=COND(I,2,K)
  CPM (I,1,K)=CPM (I,2,K)
ELSEIF (J.EQ.NJ+3) THEN
  COND(I,NJ+4,K)=COND(I,NJ+3,K)
  CPM (I,NJ+4,K)=CPM (I,NJ+3,K)
ENDIF

IF (K.EQ.2) THEN
  COND(I,J,1)=COND(I,J,2)
  CPM (I,J,1)=CPM (I,J,2)
ELSEIF (K.EQ.NK+3) THEN
  COND(I,J,NK+4)=COND(I,J,NK+3)
  CPM (I,J,NK+4)=CPM (I,J,NK+3)
ENDIF

405  CONTINUE
402 CONTINUE
  RETURN
END

```

\*\*\*\*\*  
\*\*\*\*\*

SUBROUTINE STRESS  
\*\*\*\*\*  
\*THIS SUBROUTINE CALCULATES THE SHEAR STRESSES

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
& DYYC(40),DZZC(40),DXXS(40),DYYS(40),DZZS(40)
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL20/SIG11(25,25,15),SIG12(25,25,15),SIG22(25,25,15),
& SIG13(25,25,15),SIG23(25,25,15),SIG33(25,25,15)
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
& U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
& CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)

DO 100 K=2,NK+3
DO 100 J=2,NJ+3
DO 100 I=2,NI+3

C *** CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME
  DXP1=DXXC(I+1)
  DXI =DXXC(I)
  DXM1=DXXC(I-1)

  DYP1=DYYC(J+1)
  DYJ =DYYC(J)
  DYM1=DYYC(J-1)

  DZP1=DZZC(K+1)

```

```

DZK =DZZC(K)
DZM1=DZZC(K-1)

C **** SURFACE LENGTH OF THE CONTROL VOLUME
DXN=DXXC(I)
DXS=DXXC(I)
DXF=DXXC(I)
DXB=DXXC(I)

DYF=DYYC(J)
DYB=DYYC(J)
DYE=DYYC(J)
DYW=DYYC(J)

DZE=DZZC(K)
DZW=DZZC(K)
DZN=DZZC(K)
DZS=DZZC(K)

C **** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR TEMPERATURE
DXEE=DXXS(I+2)
DXE =DXXS(I+1)
DXW =DXXS(I)
DXWW=DXXS(I-1)

DYNM=DYYM(J+2)
DYN =DYYM(J+1)
DYS =DYYM(J)
DYSS=DYYM(J-1)

DZFF=DZZS(K+2)
DZF =DZZS(K+1)
DZB =DZZS(K)
DZBB=DZZS(K-1)

C **** CALCULATE THE AVERAGE VELOCITY IN THE CENTER OF THE CVOLUME
UBAR=(U(I+1,J,K)+U(I,J,K))/2.
VBAR=(V(I,J+1,K)+V(I,J,K))/2.
WBAR=(W(I,J,K+1)+W(I,J,K))/2.

C **** CROSS-SECTIONAL AREA OF THE CV AT IT'S CENTER
DXY=DXI*DYZ
DYZ=DYJ*DZK
DZX=DZK*DXI

C **** THE NOMRAL STRESSES
SIG11(I,J,K)=2.*VIS(I,J,K)*((U(I+1,J,K)-U(I,J,K))/DXI+
& VBAR*(DXN-DXS)/DXY+WBAR*(DXF-DXB)/DZX)
& SIG22(I,J,K)=2.*VIS(I,J,K)*((V(I,J+1,K)-V(I,J,K))/DYZ+
& WBAR*(DYF-DYB)/DYZ+UBAR*(DYE-DYW)/DXY)
& SIG33(I,J,K)=2.*VIS(I,J,K)*((W(I,J,K+1)-W(I,J,K))/DZK+
& UBAR*(DZE-DZW)/DZX+VBAR*(DZN-DZS)/DYZ)

100  CONTINUE

C **** FOLLOWING DX, DY, DZ, ARE BASED ON THE LOCAL CV FOR SIG12
DO 200 K=2,NK+4

```

```

DO 200 J=2,NJ+4
DO 200 I=2,NI+4

C **** CALCULATE THE LENGTH AT VARIOUS POSITIONS
DXN=DXXS(I)
DXS=DXXS(I)
DXI=DXXS(I)

DXE=DXXC(I)
DXW=DXXC(I-1)

DYE=DYYS(J)
DYW=DYYS(J)
DYJ=DYYS(J)

DYN=DYYC(J)
DYS=DYYC(J-1)

C **** THE AVERAGE VELOCITY IN THE CONTROL VOLUME
UBAR=SILIN(U(I,J,K),U(I   ,J-1,K),DYN,DYS)
VBAR=SILIN(V(I,J,K),V(I-1,J   ,K),DXE,DXW)

C **** AVERAGE VISCOSITY
VIS12=BILIN(VIS(I   ,J,K),VIS(I   ,J-1,K),DYN,DYS,
&           VIS(I-1,J,K),VIS(I-1,J-1,K),DYN,DYS,DXE,DXW)

C **** SHEAR STRESS SIG12
SIGA=((V(I,J,K)-V(I-1,J   ,K))-VBAR*(DYE-DYW)/DYJ)/DXI
SIGB=((U(I,J,K)-U(I   ,J-1,K))-UBAR*(DXN-DXS)/DXI)/DYJ
SIG12(I,J,K)=VIS12*(SIGA+SIGB)

C **** FOLLOWING DX, DY, DZ, ARE BASED ON THE LOCAL CV FOR SIG13

C **** CALCULATE THE LENGTH AT VARIOUS POSITIONS
DXF=DXXS(I)
DXB=DXXS(I)
DXI=DXXS(I)

DXE=DXXC(I)
DXW=DXXC(I-1)

DZE=DZZS(K)
DZW=DZZS(K)
DZK=DZZS(K)

DZF=DZZC(K)
DZB=DZZC(K-1)

C **** THE AVERAGE VELOCITY IN THE CONTROL VOLUME
UBAR=SILIN(U(I,J,K),U(I   ,J,K-1),DZF,DZB)
WBAR=SILIN(W(I,J,K),W(I-1,J,K   ),DXE,DXW)

C **** AVERAGE VISCOSITY
VIS13=BILIN(VIS(I   ,J,K),VIS(I   ,J,K-1),DZF,DZB,
&           VIS(I-1,J,K),VIS(I-1,J,K-1),DZF,DZB,DXE,DXW)

```

```

C *** SHEAR STRESS SIG13
  SIGA=((W(I,J,K)-W(I-1,J,K ))-WBAR*(DZE-DZW)/DZK)/DXI
  SIGB=((U(I,J,K)-U(I ,J,K-1))-UBAR*(DXF-DXB)/DXI)/DZK
  SIG13(I,J,K)=VIS13*(SIGA+SIGB)

C *** FOLLOWING DX, DY, DZ, ARE BASED ON THE LOCAL CV FOR SIG23

C *** LENGTH AT VARIOUS POSITIONS
  DYF=DYY(S(J)
  DYB=DYY(S(J)
  DYJ=DYY(S(J)

  DYN=DYYC(J)
  DYS=DYYC(J-1)

  DZN=DZZS(K)
  DZS=DZZS(K)
  DZK=DZZS(K)

  DZF=DZZC(K)
  DZB=DZZC(K-1)

C *** THE AVERAGE VELOCITY IN THE CONTROL VOLUME
  WBAR=SILIN(W(I,J,K),W(I,J-1,K ),DYN,DYS)
  VBAR=SILIN(V(I,J,K),V(I,J ,K-1),DZF,DZB)

C *** AVERAGE VISCOSITY
  &   VIS23=BILIN(VIS(I,J,K ),VIS(I,J-1,K ),DYN,DYS,
  &   VIS(I,J,K-1),VIS(I,J-1,K-1),DYN,DYS,DZF,DZB)

  SIGA=((V(I,J,K)-V(I,J ,K-1))-VBAR*(DYF-DYB)/DYJ)/DZK
  SIGB=((W(I,J,K)-W(I,J-1,K ))-WBAR*(DZN-DZS)/DZK)/DYJ
  SIG23(I,J,K)=VIS23*(SIGA+SIGB)

200 CONTINUE
RETURN
END

*****
***** SUBROUTINE TCP *****
***** *THIS SUBROUTINE CALCULATES THE NONDIMENSIONAL TEMPERATURE AT THE
***** *THERMOCOUPLE POSITIONS.
***** ****

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&           DYYC(40),DZZC(40),DXXS(40),DYY(S(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL32/T(25,25,15),R(25,25,15),P(25,25,15),C(25,25,15),
&           U(25,25,15),V(25,25,15),W(25,25,15)
COMMON/BL38/TCOUP(30),CX(30),CY(30),CZ(30),NTH(30,3),NTHCO

C *** CALCULATE SIZE OF CONTROL VOLUME CONTAINING THE THERMOCOUPLES
DO 5100 N=1,NTHCO

```

```

      VOL=ABS((XC(NTH(N,1)+1)-XC(NTH(N,1)))*(YC(NTH(N,2)+1)-
&      YC(NTH(N,2)))*(ZC(NTH(N,3)+1)-ZC(NTH(N,3)))))
      TCOUP(N)=0.

      DO 5101 I=NTH(N,1),NTH(N,1)+1
          II=2*NTH(N,1)+1-I
          DO 5102 J=NTH(N,2),NTH(N,2)+1
              JJ=2*NTH(N,2)+1-J
              DO 5103 K=NTH(N,3),NTH(N,3)+1
                  KK=2*NTH(N,3)+1-K

C **** CORRECT TEMPERATURES FOR THERMOCOUPLES NOT LOCATED ON NODES
      TVOL=ABS((XC(I)-CX(N))*(YC(J)-CY(N))*(ZC(K)-CZ(N)))
      WVOL=TVOL/VOL
      TCOUP(N)=TCOUP(N)+WVOL*T(II,JJ,KK)

5103      CONTINUE
5102      CONTINUE
5101      CONTINUE
      IF (TCOUP(N).LT.TCOOL) TCOUP(N)=TCOOL
5100 CONTINUE

      RETURN
      END

```

```

*****
***** SUBROUTINE TRID(IST,JST,KST,ISP,JSP,KSP,PHI)
***** IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
      COMMON/BL36/AP(25,25,15),AE(25,25,15),AW(25,25,15),AN(25,25,15),
&          AS(25,25,15),AF(25,25,15),AB(25,25,15),SP(25,25,15),
&          SU(25,25,15),RI(25,25,15)
      DIMENSION A(99),B(99),C(99),PHI(25,25,15)

C **** FORWARD SWEEP IN THE X DIRECTION (FROM IST TO ISP)
      A(IST-1)=0.
      C(IST-1)=0.
      DO 100 J=JST,JSP
      DO 100 K=KST,KSP
          DO 101 I=IST,ISP
              A(I)=AE(I,J,K)
              B(I)=AW(I,J,K)
              C(I)=AN(I,J,K)*PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K)-
&                  AF(I,J,K)*PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)
              TERM=1./(AP(I,J,K)-B(I)*A(I-1))
              IF (ABS(A(I)).LE.1.0E-38) A(I)=0.0
              IF (ABS(B(I)).LE.1.0E-38) B(I)=0.0
              IF (ABS(C(I)).LE.1.0E-38) C(I)=0.0
              IF (ABS(TERM).LE.1.0E-38) TERM=0.0
              A(I)=A(I)*TERM
              C(I)=(C(I)+B(I)*C(I-1))*TERM
101      CONTINUE
              PHI(ISP,J,K)=C(ISP)
              DO 102 I=ISP-1,IST,-1

```

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        PHI(I,J,K)=A(I)*PHI(I+1,J,K)+C(I)
102      CONTINUE
100      CONTINUE

C *** FORWARD SWEEP IN THE Y DIRECTION (FROM JST TO JSP)
A(JST-1)=0.
C(JST-1)=0.
DO 200 K=KST,KSP
DO 200 I=IST,ISP
    DO 201 J=JST,JSP
        A(J)=AN(I,J,K)
        B(J)=AS(I,J,K)
        C(J)=AE(I,J,K)*PHI(I+1,J,K)+AW(I,J,K)*PHI(I-1,J,K) +
&           AF(I,J,K)*PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)
        TERM=1./(AP(I,J,K)-B(J)*A(J-1))
        IF (ABS(A(J)).LE.1.0E-38) A(J)=0.0
        IF (ABS(B(J)).LE.1.0E-38) B(J)=0.0
        IF (ABS(C(J)).LE.1.0E-38) C(J)=0.0
        IF (ABS(TERM).LE.1.0E-38) TERM=0.0
        A(J)=A(J)*TERM
        C(J)=(C(J)+B(J)*C(J-1))*TERM
201      CONTINUE
        PHI(I,JSP,K)=C(JSP)
        DO 202 J=JSP-1,JST,-1
            PHI(I,J,K)=A(J)*PHI(I,J+1,K)+C(J)
202      CONTINUE
200      CONTINUE

C *** FORWARD SWEEP IN THE Z DIRECTION (FROM KST TO KSP)
A(KST-1)=0.
C(KST-1)=0.
DO 300 I=IST,ISP
DO 300 J=JST,JSP
    DO 301 K=KST,KSP
        A(K)=AF(I,J,K)
        B(K)=AB(I,J,K)
        C(K)=AE(I,J,K)*PHI(I+1,J,K)+AW(I,J,K)*PHI(I-1,J,K) +
&           AN(I,J,K)*PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K)+SU(I,J,K)
        TERM=1./(AP(I,J,K)-B(K)*A(K-1))
        IF (ABS(A(K)).LE.1.0E-38) A(K)=0.0
        IF (ABS(B(K)).LE.1.0E-38) B(K)=0.0
        IF (ABS(C(K)).LE.1.0E-38) C(K)=0.0
        IF (ABS(TERM).LE.1.0E-38) TERM=0.0
        A(K)=A(K)*TERM
        C(K)=(C(K)+B(K)*C(K-1))*TERM
301      CONTINUE
        PHI(I,J,KSP)=C(KSP)
        DO 302 K=KSP-1,KST,-1
            PHI(I,J,K)=A(K)*PHI(I,J,K+1)+C(K)
302      CONTINUE
300      CONTINUE

C *** REVERSE SWEEP IN X DIRECTION (FROM ISP TO IST)
B(KSP+1)=0.
C(KSP+1)=0.
DO 600 I=ISP,IST,-1

```

```

DO 600 J=JSP,JST,-1
  DO 601 K=KSP,KST,-1
    A(K)=AF(I,J,K)
    B(K)=AB(I,J,K)
    C(K)=AE(I,J,K)*PHI(I+1,J,K)+AW(I,J,K)*PHI(I-1,J,K)+  

    &      AN(I,J,K)*PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K)+SU(I,J,K)
    TERM=1./(AP(I,J,K)-A(K)*B(K+1))
    B(K)=B(K)*TERM
    C(K)=(C(K)+A(K)*C(K+1))*TERM
    IF (ABS(A(K)).LE.1.0E-38) A(K)=0.0
    IF (ABS(B(K)).LE.1.0E-38) B(K)=0.0
    IF (ABS(C(K)).LE.1.0E-38) C(K)=0.0
601   CONTINUE
    PHI(I,J,KST)=C(KST)
    DO 602 K=KST+1,KSP
      PHI(I,J,K)=B(K)*PHI(I,J,K-1)+C(K)
602   CONTINUE
600 CONTINUE

C *** REVERSE SWEEP IN THE Y DIRECTION (FROM JSP TO JST)
B(JSP+1)=0.
C(JSP+1)=0.
DO 500 K=KSP,KST,-1
DO 500 I=ISP,IST,-1
  DO 501 J=JSP,JST,-1
    A(J)=AN(I,J,K)
    B(J)=AS(I,J,K)
    C(J)=AE(I,J,K)*PHI(I+1,J,K)+AW(I,J,K)*PHI(I-1,J,K)+  

    &      AF(I,J,K)*PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)
    TERM=1./(AP(I,J,K)-A(J)*B(J+1))
    B(J)=B(J)*TERM
    C(J)=(C(J)+A(J)*C(J+1))*TERM
    IF (ABS(A(J)).LE.1.0E-38) A(J)=0.0
    IF (ABS(B(J)).LE.1.0E-38) B(J)=0.0
    IF (ABS(C(J)).LE.1.0E-38) C(J)=0.0
501   CONTINUE
    PHI(I,JST,K)=C(JST)
    DO 502 J=JST+1,JSP
      PHI(I,J,K)=B(J)*PHI(I,J-1,K)+C(J)
502   CONTINUE
500 CONTINUE

C *** REVERSE SWEEP IN THE Z DIRECTION (FROM KSP TO KST)
B(ISP+1)=0.
C(ISP+1)=0.
DO 400 J=JSP,JST,-1
DO 400 K=KSP,KST,-1
  DO 401 I=ISP,IST,-1
    A(I)=AE(I,J,K)
    B(I)=AW(I,J,K)
    C(I)=AN(I,J,K)*PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K)+  

    &      AF(I,J,K)*PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)
    TERM=1./(AP(I,J,K)-A(I)*B(I+1))
    B(I)=B(I)*TERM
    C(I)=(C(I)+A(I)*C(I+1))*TERM
    IF (ABS(A(I)).LE.1.0E-38) A(I)=0.0

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```

        IF (ABS(B(I)).LE.1.0E-38) B(I)=0.0
        IF (ABS(C(I)).LE.1.0E-38) C(I)=0.0
401    CONTINUE
        PHI(IST,J,K)=C(IST)
        DO 402 I=IST+1,ISP
              PHI(I,J,K)=B(I)*PHI(I-1,J,K)+C(I)
402    CONTINUE
400    CONTINUE

        RETURN
        END

```

```
*****
*****
```

#### SUBROUTINE VIEW

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*****
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```

* NTHS      = TOTAL NUMBER OF NODES CONTAINING HEAT SOURCE
* NFX,NFY,NFZ = NUMBER OF NODES IN HEAT SOURCE PER DIRECTION
* FX,FY,FZ   = STARTING COORDINATES OF HEAT SOURCE
* DXS,DYS,DZS = LENGTH IN EACH DIRECTION ON THE SOUTH SURFACE
*                 OF THE ENCLOSURE
* SXS,SYS,SZS = COORDINATES OF THE SURFACE ELEMENT (USED TO
*                 CALCULATE THE DISTANCE TO HEAT SOURCE)
* VFHSE, VFHSE = VIEW FACTOR FROM THE HEAT SOURCE TO WEST, EAST
*                 SURFACES OF THE ENCLOSURE
* RSQW,RSQE   = SQUARE OF DISTANCE FROM THE HEAT SOURCE TO THE
*                 WEST, EAST SURFACE ELEMENT.
*
```

```

*                 NODES 2 THRU NI,2 THRU NJ AND 2 THRU NK ARE CONTAINED
*                 INSIDE THE WALL, RADIATION EFFECTS INVOLVE ONLY NODES
*                 3 THRU NIM1, 3 THRU NJM1, AND 3 THRU NKM1
*
```

```

* VFHSBW(N,M,I,J),
* VFHSBE(N,M,I,J) = VIEW FACTOR FROM FIRE NODE N TO ELEMENT (I,J) OF
*                 WEST, EAST SURFACES OF CV M.
*****
```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
&           DYYC(40),DZZC(40),DXXS(40),DYYYS(40),DZZS(40)
COMMON/BL1/DX,DY,DZ,DTIME,TCOOL,PI,Q,QR
COMMON/BL2/X,Y,H,TFLR,TWAL
COMMON/BL7/NI,NJ,NK,KRUN,NBLOR,NWRP
COMMON/BL22/CPS(20),CONS(20),WFAN(20),NCHIP,ICHIPB(20),NCHPI(20),
&           JCHPB(20),NCHPJ(20),KCHPB(20),NCHPK(20)
COMMON/BL37/VIS(25,25,15),COND(25,25,15),RESORM(40),
&           CPM(25,25,15),NHSZ(3,2),NOD(25,25,15)
COMMON/BL40/VFHSE(5,25,15),VFHSS(5,15,25),
&           VFHSN(5,15,25),VFHSB(5,25,25),VFHSF(5,25,25)
COMMON/BL41/VFHSBW(5,8,34,34),VFHSBE(5,8,34,34),VFHSBS(5,8,34,34),
&           VFHSBN(5,8,34,34),VFHSBB(5,8,34,34),VFHSBF(5,8,34,34)

```

```
NTHS=NHSZ(3,2)-NHSZ(3,1)+1
```

```
DO 500 N=1,NTHS
```

```
SUMM=0.
```

```
NFX=NHSZ(1,1)
```

```

NFY=NHSZ(2,1)
NFZ=NHSZ(3,1)-1+N
FX =XS(NFX+1)
FY =YS(NFY+1)
FZ =ZS(NFZ+1)

C *** VIEW FACTOR FROM FIRE TO WEST & EAST SURFACES OF ENCLOSURE
DO 100 J=3,NJ+2
DO 100 K=3,NK+2
  DYW=DYYC(J)
  DYE=DYYC(J)
  DZW=DZZC(K)
  DZE=DZZC(K)

  SXW=XS(3)
  SXE=XS(NI+3)
  SYW=YC(J)
  SYE=YC(J)
  SZW=ZC(K)
  SZE=ZC(K)

  DYZW=DYW*DZW
  DYZE=DYE*DZE

  RSQW=(FX-SXW)**2+(FY-SYW)**2+(FZ-SZW)**2
  RSQE=(FX-SXE)**2+(FY-SYE)**2+(FZ-SZE)**2

  VFHSW(N,J,K)=SQRT((FX-SXW)**2/RSQW)*DYZW/(4.0*PI*RSQW)
  VFHSE(N,J,K)=SQRT((FX-SXE)**2/RSQE)*DYZE/(4.0*PI*RSQE)
  SUMM=SUMM+VFHSW(N,J,K)+VFHSE(N,J,K)
100 CONTINUE

C *** VIEW FACTOR FROM FIRE TO NORTH & SOUTH SURFACES OF ENCLOSURE
DO 200 I=3,NI+2
DO 200 K=3,NK+2
  DXS=DXXC(I)
  DXN=DXXC(I)
  DZS=DZZC(K)
  DZN=DZZC(K)

  SZN=XC(I)
  SXS=XC(I)
  SYN=YS(NJ+3)
  SYS=YS(3)
  SZN=ZC(K)
  SXS=ZC(K)

  DZXS=DXS*DZS
  DZXN=DXN*DZN

  RSQS=(FX-SXS)**2+(FY-SYS)**2+(FZ-SZS)**2
  RSQN=(FX-SZN)**2+(FY-SYN)**2+(FZ-SZN)**2

  VFHSS(N,K,I)=SQRT((FY-SYS)**2/RSQS)*DZXS/(4.0*PI*RSQS)
  VFHSN(N,K,I)=SQRT((FY-SYN)**2/RSQN)*DZXN/(4.0*PI*RSQN)
  SUMM=SUMM+VFHSS(N,K,I)+VFHSN(N,K,I)

```

200 CONTINUE

C \*\*\* VIEW FACTOR FROM FIRE TO FRONT & BACK SURFACES OF ENCLOSURE  
DO 300 I=3,NI+2  
DO 300 J=3,NJ+2  
DXF=DXXC(I)  
DXB=DXXC(I)  
DYF=DYYC(J)  
DYB=DYYC(J)  
SXF=XC(I)  
SXB=XC(I)  
SYF=YC(J)  
SYB=YC(J)  
SZF=ZS(NK+3)  
SZB=ZS(3)  
DXYB=DXB\*DYB  
DXYF=DXF\*DYF  
RSQB=(FX-SXB)\*\*2+(FY-SYB)\*\*2+(FZ-SZB)\*\*2  
RSQF=(FX-SXF)\*\*2+(FY-SYF)\*\*2+(FZ-SZF)\*\*2  
VFHSB(N,I,J)=SQRT((FZ-SZB)\*\*2/RSQB)\*DXYB/(4.0\*PI\*RSQB)  
VFHSF(N,I,J)=SQRT((FZ-SZF)\*\*2/RSQF)\*DXYF/(4.0\*PI\*RSQF)  
SUMM=SUMM+VFHSB(N,I,J)+VFHSF(N,I,J)  
300 CONTINUE  
C \*\*\* MODIFY VIEW FACTORS SO THEIR SUMMATION EQUALS UNITY.  
DO 150 J=3,NJ+2  
DO 150 K=3,NK+2  
VFHSW(N,J,K)=VFHSW(N,J,K)/SUMM  
VFHSE(N,J,K)=VFHSE(N,J,K)/SUMM  
150 CONTINUE  
DO 250 K=3,NK+2  
DO 250 I=3,NI+2  
VFHSS(N,K,I)=VFHSS(N,K,I)/SUMM  
VFHSN(N,K,I)=VFHSN(N,K,I)/SUMM  
250 CONTINUE  
DO 350 I=3,NI+2  
DO 350 J=3,NJ+2  
VFHSB(N,I,J)=VFHSB(N,I,J)/SUMM  
VFHSF(N,I,J)=VFHSF(N,I,J)/SUMM  
350 CONTINUE  
IF (NCHIP.LT.NBLOR) GOTO 500  
C \*\*\* CALCULATE VIEW FACTORS FROM FIRE N TO INTERNAL SOLID BLOCKS  
C \*\*\* (BLOCKS ARE ONLY THOSE NOT INCLUDED IN THE WALL)  
C \*\*\* VIEW FACTOR FROM THE FIRE TO WEST & EAST SURFACES OF BLOCK M  
DO 900 M=1,NCHIP-NBLOR+1  
IB =ICHPB(M+NBLOR-1)  
IE =IB+NCHPI(M+NBLOR-1)-1  
JB =JCHPB(M+NBLOR-1)  
JE =JB+NCHPJ(M+NBLOR-1)-1

```

KB  =KCHPB(M+NBLOR-1)
KE  =KB+NCHPK(M+NBLOR-1)-1

SXW=XS(IB)
SXE=XE(IE)

DO 400 JJ=JB,JE-1
DO 400 KK=KB,KE-1
  DYW=DYYC(JJ)
  DYE=DYYC(JJ)
  DZW=DZZC(KK)
  DZE=DZZC(KK)

  SYW=YC(JJ)
  SYE=YC(JJ)
  SZW=ZC(KK)
  SZE=ZC(KK)

  DYZW=DYW*DZW
  DYZE=DYE*DZE

  RSQW=(FX-SXW)**2+(FY-SYW)**2+(FZ-SZW)**2
  RSQE=(FX-SXE)**2+(FY-SYE)**2+(FZ-SZE)**2
  VFHSBW(N,M,JJ,KK)=SQRT((FX-SXW)**2/RSQW)*DYZW/(4.0*PI*RSQW)
  VFHSBE(N,M,JJ,KK)=SQRT((FX-SXE)**2/RSQE)*DYZE/(4.0*PI*RSQE)

C *** MODIFY VIEW FACTORS DUE TO INTRODUCTION OF INTERNAL BLOCKS
  IF (SXE.LT.FX) VFHSBW(N,M,JJ,KK)=0.
  IF (SXW.GT.FX) VFHSBE(N,M,JJ,KK)=0.

C *** THE FIRE CAN'T SEE THE WEST AND EAST SURFACES OF THE BLOCK
  IF (SXW.LE.FX.AND.SXE.GE.FX) THEN
    VFHSBW(N,M,JJ,KK)=0.
    VFHSBE(N,M,JJ,KK)=0.
  ENDIF
400    CONTINUE

C *** CHECK TO SEE IF ANY ELEMENT ON THE WALL IS SHADED BY A SOLID BLOCK.

C *** CHECK WEST AND EAST WALLS OF ENCLOSURE
  DO 410 J=3,NJ+2
  DO 410 K=3,NK+2

C *** THE BLOCK IS ON THE WEST SIDE OF THE FIRE
  IF (SXE.LT.FX) THEN
    NVIW=NVIWX(FX,FY,FZ,XS(3),YC(J),ZC(K),SXE,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSW(N,J,K)=0.
  ENDIF

C *** THE BLOCK IS ON THE EAST SIDE OF THE FIRE
  IF (SXW.GT.FX) THEN
    NVIW=NVIWX(FX,FY,FZ,XS(NI+3),YC(J),ZC(K),SXW,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
  ENDIF

```

410 CONTINUE

C \*\*\* CHECK SOUTH AND NORTH WALLS OF THE ENCLOSURE

DO 420 K=3,NK+2

DO 420 I=3,NI+2

C \*\*\* THE BLOCK IS ON THE WEST SIDE OF THE FIRE

IF (SXE.LT.FX.AND.XC(I).LT.FX) THEN

NVIW=NVIWX(FX,FY,FZ,XC(I),YS(3),ZC(K),SXE,

&

IB,JB,KB,IE,JE,KE)

IF (NVIW.EQ.1) VFHSS(N,K,I)=0.

NVIW=NVIWX(FX,FY,FZ,XC(I),YS(NJ+3),ZC(K),SXE,

&

IB,JB,KB,IE,JE,KE)

IF (NVIW.EQ.1) VFHSN(N,K,I)=0.

ENDIF

C \*\*\* THE BLOCK IS ON THE EAST SIDE OF THE FIRE

IF (SXW.GT.FX.AND.XC(I).GT.FX) THEN

NVIW=NVIWX(FX,FY,FZ,XC(I),YS(3),ZC(K),SXW,

&

IB,JB,KB,IE,JE,KE)

IF (NVIW.EQ.1) VFHSS(N,K,I)=0.

NVIW=NVIWX(FX,FY,FZ,XC(I),YS(NJ+3),ZC(K),SXW,

&

IB,JB,KB,IE,JE,KE)

IF (NVIW.EQ.1) VFHSN(N,K,I)=0.

ENDIF

420 CONTINUE

C \*\*\* CHECK BACK AND FRONT WALLS OF ENCLOSURE

DO 430 I=3,NI+2

DO 430 J=3,NJ+2

C \*\*\* THE BLOCK IS ON THE WEST SIDE OF THE FIRE

IF (SXE.LT.FX.AND.XC(I).LT.FX) THEN

NVIW=NVIWX(FX,FY,FZ,XC(I),YC(J),ZS(3),SXE,

&

IB,JB,KB,IE,JE,KE)

IF (NVIW.EQ.1) VFHSB(N,I,J)=0.

NVIW=NVIWX(FX,FY,FZ,XC(I),YC(J),ZS(NK+3),SXE,

&

IB,JB,KB,IE,JE,KE)

IF (NVIW.EQ.1) VFHSF(N,I,J)=0.

ENDIF

C \*\*\* THE BLOCK IS ON THE EAST SIDE OF THE FIRE

IF (SXW.GT.FX.AND.XC(I).GT.FX) THEN

NVIW=NVIWX(FX,FY,FZ,XC(I),YC(J),ZS(3),SXW,

&

IB,JB,KB,IE,JE,KE)

IF (NVIW.EQ.1) VFHSB(N,I,J)=0.

NVIW=NVIWX(FX,FY,FZ,XC(I),YC(J),ZS(NK+3),SXW,

&

IB,JB,KB,IE,JE,KE)

IF (NVIW.EQ.1) VFHSF(N,I,J)=0.

ENDIF

430 CONTINUE

C \*\*\* VIEW FACTOR FROM FIRE TO NORTH & SOUTH SURFACES OF BLOCK M

DO 600 II=IB,IE-1

DO 600 KK=KB,KE-1

DXN=DXXC(II)

--

```

DXS=DXXC(II)
DZN=DZZC(KK)
DZS=DZZC(KK)

SXN=XC(II)
SXS=XC(II)
SYN=YS(JE)
SYS=YS(JB)
SZN=ZC(KK)
SZS=ZC(KK)

DZXN=DXN*DZN
DZXS=DXS*DZS

RSQS=(FX-SXS)**2+(FY-SYS)**2+(FZ-SZS)**2
RSQN=(FX-SXN)**2+(FY-SYN)**2+(FZ-SZN)**2
VFHSBS(N,M,KK,II)=SQRT((FY-SYS)**2/RSQS)*DZXS/(4.0*PI*RSQS)
VFHSBN(N,M,KK,II)=SQRT((FY-SYN)**2/RSQN)*DZXN/(4.0*PI*RSQN)

C *** MODIFY VIEW FACTORS DUE TO INTRODUCTION OF INTERNAL BLOCKS
  IF (SYN.LT.FY) VFHSBS(N,M,KK,II)=0.
  IF (SYS.GT.FY) VFHSBN(N,M,KK,II)=0.
  IF (SYS.LE.FY.AND.SYN.GE.FY) THEN
    VFHSBS(N,M,KK,II)=0.
    VFHSBN(N,M,KK,II)=0.
  ENDIF
600    CONTINUE

C *** CHECK IF ANY ELEMENT ON WALL IS SHADED BY INTERNAL SOLID BLOCKS

C *** CHECK WEST AND EAST WALLS OF THE ENCLOSURE
  DO 610 J=3,NJ+2
  DO 610 K=3,NK+2

C *** THE BLOCK IS ON THE SOUTH SIDE OF THE FIRE
  IF (SYN.LT.FY.AND.YC(J).LT.FY) THEN
    NVIW=NVIWY(FX,FY,FZ,XS(3),YC(J),ZC(K),SYN,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
    NVIW=NVIWY(FX,FY,FZ,XS(NI+3),YC(J),ZC(K),SYN,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
  ENDIF

C *** THE BLOCK IS ON THE NORTH SIDE OF THE FIRE
  IF (SYS.GT.FY.AND.YC(J).GT.FY) THEN
    NVIW=NVIWY(FX,FY,FZ,XS(3),YC(J),ZC(K),SYS,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
    NVIW=NVIWY(FX,FY,FZ,XS(NI+3),YC(J),ZC(K),SYS,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
  ENDIF
610    CONTINUE

C *** CHECK THE SOUTH AND NORTH WALLS OF THE ENCLOSURE

```

```

DO 620 K=3,NK+2
DO 620 I=3,NI+2

C *** THE BLOCK IS ON THE SOUTH SIDE OF THE FIRE
    IF (SYN.LT.FY) THEN
        NVIW=NVIWY(FX,FY,FZ,XC(I),YS(3),ZC(K),SYN,
        &           IB,JB,KB,IE,JE,KE)
        IF (NVIW.EQ.1) VFHSS(N,K,I)=0.
    ENDIF

C *** THE BLOCK IS ON THE NORTH SIDE OF THE FIRE
    IF (SYS.GT.FY) THEN
        NVIW=NVIWY(FX,FY,FZ,XC(I),YS(NJ+3),ZC(K),SYS,
        &           IB,JB,KB,IE,JE,KE)
        IF (NVIW.EQ.1) VFHSN(N,K,I)=0.
    ENDIF
620     CONTINUE

C *** THE BACK AND FRONT WALLS OF THE ENCLOSURE
    DO 630 I=3,NI+2
    DO 630 J=3,NJ+2

C *** THE BLOCK IS ON THE SOUTH SIDE OF THE FIRE
    IF (SYN.LT.FY.AND.YC(J).LT.FY) THEN
        NVIW=NVIWY(FX,FY,FZ,XC(I),YC(J),ZS(3),SYN,
        &           IB,JB,KB,IE,JE,KE)
        IF (NVIW.EQ.1) VFHSB(N,I,J)=0.
        NVIW=NVIWY(FX,FY,FZ,XC(I),YC(J),ZS(NK+3),SYN,
        &           IB,JB,KB,IE,JE,KE)
        IF (NVIW.EQ.1) VFHSF(N,I,J)=0.
    ENDIF

C *** THE BLOCK IS ON THE NORTH SIDE OF THE FIRE
    IF (SYS.GT.FY.AND.YC(J).GT.FY) THEN
        NVIW=NVIWY(FX,FY,FZ,XC(I),YC(J),ZS(3),SYS,
        &           IB,JB,KB,IE,JE,KE)
        IF (NVIW.EQ.1) VFHSB(N,I,J)=0.
        NVIW=NVIWY(FX,FY,FZ,XC(I),YC(J),ZS(NK+3),SYS,
        &           IB,JB,KB,IE,JE,KE)
        IF (NVIW.EQ.1) VFHSF(N,I,J)=0.
    ENDIF
630     CONTINUE

C *** CHECK VIEW FACTORS FROM FIRE TO BACK & FRONT SURFACES OF BLOCK M
    DO 700 II=IB,IE-1
    DO 700 JJ=JB,JE-1
        DXF=DXXC(II)
        DXB=DXXC(II)
        DYF=DYYC(JJ)
        DYB=DYYC(JJ)

        DXYB=DXB*DYB
        DXYF=DXF*DYF

        SXF=XC(II)
        SXB=XC(II)

```

```

SYF=YC(JJ)
SYB=YC(JJ)
SZF=ZS(KE)
SZB=ZS(KB)

RSQB=(FX-SXB)**2+(FY-SYB)**2+(FZ-SZB)**2
RSQF=(FX-SXF)**2+(FY-SYF)**2+(FZ-SZF)**2
VFHSBB(N,M,II,JJ)=(FZ-SZB)**2*DXYB/(4.0*PI*RSQB**2)
VFHSBF(N,M,II,JJ)=(FZ-SZF)**2*DXYF/(4.0*PI*RSQF**2)

C *** MODIFY VIEW FACTORS DUE TO INTRODUCTION OF INTERNAL SOLID BLOCKS
  IF (SZF.LT.FZ) VFHSBB(N,M,II,JJ)=0.
  IF (SZB.GT.FZ) VFHSBF(N,M,II,JJ)=0.
  IF (SZB.LE.FZ.AND.SZF.GE.FZ) THEN
    VFHSBB(N,M,II,JJ)=0.
    VFHSBF(N,M,II,JJ)=0.
  ENDIF
700    CONTINUE

C *** CHECK IF ANY ELEMENT ON THE WALL IS SHADED BY SOLID BLOCK.

C *** THE WEST AND EAST WALLS OF THE ENCLOSURE
  DO 710 J=3,NJ+2
  DO 710 K=3,NK+2

C *** THE BLOCK IS ON THE BACK SIDE OF THE FIRE
  IF (SZF.LT.FZ.AND.ZC(K).LT.FZ) THEN
    NVIW=NVIWZ(FX,FY,FZ,XS(3),YC(J),ZC(K),SZF,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
    NVIW=NVIWZ(FX,FY,FZ,XS(NI+3),YC(J),ZC(K),SZF,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
  ENDIF

C *** THE BLOCK IS ON THE FRONT SIDE OF THE FIRE
  IF (SZB.GT.FZ.AND.ZC(K).GT.FZ) THEN
    NVIW=NVIWZ(FX,FY,FZ,XS(3),YC(J),ZC(K),SZB,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
    NVIW=NVIWZ(FX,FY,FZ,XS(NI+3),YC(J),ZC(K),SZB,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSE(N,J,K)=0.
  ENDIF
710    CONTINUE

C *** CHECK THE SOUTH AND NORTH WALLS OF THE ENCLOSURE
  DO 720 K=3,NK+2
  DO 720 I=3,NI+2

C *** THE BLOCK IS ON THE BACK SIDE OF THE FIRE
  IF (SZF.LT.FZ.AND.ZC(K).LT.FZ) THEN
    NVIW=NVIWZ(FX,FY,FZ,XC(I),YS(3),ZC(K),SZF,
    &           IB,JB,KB,IE,JE,KE)
    IF (NVIW.EQ.1) VFHSS(N,K,I)=0.
    NVIW=NVIWZ(FX,FY,FZ,XC(I),YS(NJ+3),ZC(K),SZF,

```

```

&           IB,JB,KB,IE,JE,KE)
      IF (NVIW.EQ.1) VFHSN(N,K,I)=0.
      ENDIF

C *** THE BLOCK IS ON THE FRONT SIDE OF THE FIRE
      IF (SZB.GT.FZ.AND.ZC(K).GT.FZ) THEN
          NVIW=NVIWZ(FX,FY,FZ,XC(I),YS(3),ZC(K),SZB,
&           IB,JB,KB,IE,JE,KE)
          IF (NVIW.EQ.1) VFHSS(N,K,I)=0.
          NVIW=NVIWZ(FX,FY,FZ,XC(I),YS(NJ+3),ZC(K),SZB,
&           IB,JB,KB,IE,JE,KE)
          IF (NVIW.EQ.1) VFHSN(N,K,I)=0.
      ENDIF
720    CONTINUE

C *** CHECK THE BACK AND FRONT WALLS OF THE ENCLOSURE
      DO 730 I=3,NI+2
      DO 730 J=3,NJ+2

C *** THE BLOCK IS ON THE BACK SIDE OF THE FIRE
      IF (SZF.LT.FZ) THEN
          NVIW=NVIWZ(FX,FY,FZ,XC(I),YC(J),ZS(3),SZF,
&           IB,JB,KB,IE,JE,KE)
          IF (NVIW.EQ.1) VFHSB(N,I,J)=0.
      ENDIF

C *** THE BLOCK IS ON THE FRONT SIDE OF THE FIRE
      IF (SZB.GT.FZ) THEN
          NVIW=NVIWZ(FX,FY,FZ,XC(I),YC(J),ZS(NK+3),SZB,
&           IB,JB,KB,IE,JE,KE)
          IF (NVIW.EQ.1) VFHSF(N,I,J)=0.
      ENDIF
730    CONTINUE
900    CONTINUE
500    CONTINUE

```

```

RETURN
END

```

```

*****
***** FUNCTION BILIN(V1,V2,D1,D2,V3,V4,D3,D4,D5,D6)
*****
* BI-LINEAR INTERPOLATION

```

```

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
V12=(V1*D2+V2*D1)/(D1+D2)
V34=(V3*D4+V4*D3)/(D3+D4)
BILIN=(V12*D6+V34*D5)/(D5+D6)

```

```

RETURN
END

```

```

*****
*****
```

```

INTEGER FUNCTION NVIWX(FX,FY,FZ,X1,Y1,Z1,X3,IB,JB,KB,IE,JE,KE)
*****
*USED ONLY IN SUBROUTINE VIEW

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
& DYYC(40),DZZC(40),DXXS(40),DYYS(40),DZZS(40)

NVIWX=0
TPARA=(X3-X1)/(FX-X1)
Y3=(FY-Y1)*TPARA+Y1
Z3=(FZ-Z1)*TPARA+Z1
IF (Y3.LE.YS(JE).AND.Y3.GE.YS(JB)) THEN
    IF (Z3.LE.ZS(KE).AND.Z3.GE.ZS(KB)) NVIWX=1
ENDIF

RETURN
END

*****
INTEGER FUNCTION NVIWy(FX,FY,FZ,X1,Y1,Z1,Y3,IB,JB,KB,IE,JE,KE)
*****
*USED ONLY IN SUBROUTINE VIEW

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
& DYYC(40),DZZC(40),DXXS(40),DYYS(40),DZZS(40)

NVIWy=0
TPARA=(Y3-Y1)/(FY-Y1)
X3=(FX-X1)*TPARA+X1
Z3=(FZ-Z1)*TPARA+Z1
IF (X3.LE.XS(IE).AND.X3.GE.XS(IB)) THEN
    IF (Z3.LE.ZS(KE).AND.Z3.GE.ZS(KB)) NVIWy=1
ENDIF

RETURN
END

*****
INTEGER FUNCTION NVIWZ(FX,FY,FZ,X1,Y1,Z1,Z3,IB,JB,KB,IE,JE,KE)
*****
*USED ONLY IN SUBROUTINE VIEW

IMPLICIT DOUBLE PRECISION (A-H,O-Z)
COMMON/R4/XC(40),YC(40),ZC(40),XS(40),YS(40),ZS(40),DXXC(40),
& DYYC(40),DZZC(40),DXXS(40),DYYS(40),DZZS(40)

NVIWZ=0
TPARA=(Z3-Z1)/(FZ-Z1)
Y3=(FY-Y1)*TPARA+Y1
X3=(FX-X1)*TPARA+X1
IF (Y3.LE.YS(JE).AND.Y3.GE.YS(JB)) THEN
    IF (X3.LE.XS(IE).AND.X3.GE.XS(IB)) NVIWZ=1

```

```
ENDIF
```

```
RETURN
```

```
END
```

```
*****
```

```
*****
```

```
FUNCTION SILIN(V1,V2,D1,D2)
```

```
*****
```

```
* SINGLE LINEAR INTERPOLATION
```

```
IMPLICIT DOUBLE PRECISION (A-H,O-Z)
```

```
SILIN=(V1*D2+V2*D1)/(D1+D2)
```

```
RETURN
```

```
END
```

## APPENDIX C. PROGRAM ISOTHERM

This program generates two dimensional isotherm plots using the National Center for Atmospheric Research (NCAR) Graphics software, from three dimensional temperature field data produced by program FIRE.

### PROGRAM ISOTHERM

```
*****
* This program uses NCAR GRAPHICS to calculate and plot isotherms in *
* an arbitrary two dimensional section with uniform grid spacing      *
* from a non-uniform three dimensional grid using linear interpola-  *
* tion routines. Isotherms are plotted using 14 equal size color        *
* ranges based on the maximum temperature in the 3-D grid.            *
*****
*Variables used in this program. Arrays names are followed by left and
*      right parenthesis (). (NOTE: some variables used in the plotting
*      routines have been specifically omitted from this list)
*
* bth      : Non-dimensional compartment breadth (X-direction)
* cx       : Interpolation parameter used to generate 2-D grid
* cy       : Interpolation parameter used to generate 2-D grid
* c1       : Interpolation parameter used to locate desired 3-D section
* c2       : Interpolation parameter used to locate desired 3-D section
* c11      : Interpolation parameter used to generate 2-D grid
* c12      : Interpolation parameter used to generate 2-D grid
* c21      : Interpolation parameter used to generate 2-D grid
* c22      : Interpolation parameter used to generate 2-D grid
* dx       : Non-dimensional 3-D grid size inside compartment, X dir.
*           (redefined in SUBROUTINE SCTN as non-dimensional uniform
*           grid spacing in the X direction for the 2-D plot)
* dy       : Non-dimensional 3-D grid size inside compartment, Y dir.
*           (redefined in SUBROUTINE SCTN as non-dimensional uniform
*           grid spacing in the Y direction for the 2-D plot)
* dz       : Non-dimensional 3-D grid size inside compartment, Z dir.
* h        : Non-dimensional Z length of compartment to model
* iplot    : Number of grids in X direction of 2-D grid
* iscn    : If >0 hold X constant, else =0
* ixx     : Number of X grid points in "xxs" array
* jplot    : Number of grids in Y direction of 2-D grid
* jscn    : If >0 hold Y constant, else =0
* jyy     : Number of Y grid points in "yys" array
* kscn    : If >0 hold Z constant, else =0
* ncrmax : Maximum number of contours
* ni      : Number of cells across compartment, X dir.
* nj      : Number of cells across compartment, Y dir.
* nk      : Number of cells across compartment, Z dir.
* nstop   : Control variable to terminate program
```

```

* nview   : Input value of desired plot (from SUBROUTINE SECTION)
* t()     : Imported array of temperature values
* ta      : Ambient absolute temperature prior to fire ignition
* temp()  : Temperatures of desired section of 3-D grid
* tflr    : Non-dimensional thickness of compartment floor/ceiling
* time    : Dimensional time (in seconds) since fire ignition
* tmax    : Maximum temperature in "temp" array (redefined in SUBROUTINE
*           SECTION as maximum temperature in interpolated 2-D array "tt")
* tt()    : Section temperatures interpolated to 2-D grid
* twal    : Non-dimensional thickness of compartment walls
* wth     : Non-dimensional compartment width (Y-direction)
* x       : Non-dimensional X length of compartment to model
* xfrn1   : Starting 2-D, X coordinate of section to zoom in on
* xfrn2   : Ending 2-D, X coordinate of section to zoom in on
* xs()    : Non-dimensional grid locations
* xscn   : X location where Y-Z plane to be taken
* XSS()   : Non-dimensional staggered grid locations
* xtime   : Non-dimensional time since fire ignition
* xx      : Non-dimensional length of 2-D X axis
* xxs()   : 3-D grid points to be used as X coordinate in 2-D plot
* y       : Non-dimensional Y length of compartment to model
* yfrn1   : Starting 2-D, Y coordinate of section to zoom in on
* yfrn2   : Ending 2-D, Y coordinate of section to zoom in on
* yscn   : Y location where X-Z plane to be taken
* yy      : Non-dimensional length of 2-D Y axis
* yys()   : 3-D grid points to be used as Y coordinate in 2-D plot
* zscn   : Z location where X-Y plane to be taken
*****
```

```

C *** INPUT DATA FROM PROGRAM "FIRE"
call INPUT
```

```

C *** GENERATE GRID
call GRID
```

```

C *** DEFINE DESIRED SECTION
5 call SECTION(nstop)
```

```

C *** CHECK IF FINISHED WITH PROGRAM
if (nstop.ne.0) goto 9999
```

```

C *** LOCATE DESIRED SECTION TO PLOT
call INTERPOL
```

```

C *** INTERPOLATE TO A 2-D PLOT
call SCTN
```

```

C *** DEVELOP PLOT USING NCAR GRAPHICS
call PLOT
```

```

C *** LOOP BACK FOR ANOTHER SECTION
goto 5
```

```

C *** FINISHED WITH PROGRAM
9999 end
*****
```

```

BLOCK DATA
*****
* The variables IPLOT and JPLOT must be changed in order to vary the *
* number of grids in the uniform 2-D plot. NCRMAX must be changed to *
* vary the maximum number of colors allowed by the NCAR plots (NOTE: *
* NCRMAX must include one value for the default foreground color). *
*****
***** implicit real*8 (a-h,o-z)
common/ugrd/iplot,jplot,ncrmax
common/sct1/iscn,jscn,kscn,nview

data iplot,jplot,ncrmax/24,24,15/
data nview/0/

end
*****
SUBROUTINE SECTION(nstop)
*****
implicit real*8 (a-h,o-z)
common/fctn/xfrn1,xfrn2,yfrn1,yfrn2
common/sct1/iscn,jscn,kscn,nview
common/sct2/xscn,yscn,zscn
common/bl2/x,y,h,tflr,twal,ta

99 print *
print *
print *, 'Enter For:'
print *, __
print *, ' 0   Finished with program'
print *, ' 1   Plan View (X-Y Plane)'
print *, ' 2   X-Z Profile'
print *, ' 3   Y-Z Profile'
if(nview.le.0) goto 97
print *, ' 4   Enlargement of portion of previous plot'
97 print *
print *, 'Enter the desired isotherm plot:'
read (*,*) nview
nstop=0
xfrn1=0.
xfrn2=1.
yfrn1=0.
yfrn2=1.

c *** END PROGRAM
if(nview.eq.0) then
  nstop=9999

C *** PLOT AN X-Y PLANE (a.k.a. Z section)
elseif(nview.eq.1) then
  iscn=0
  jscn=0
  kscn=1

```

```

xscn=0.
yscn=0.
10 print *
7 format (1x,a/1x,a,f5.2,a)
print 7,
&   'Enter height of desired view plane in feet above the floor',
&   '(Floor = 0.0; Ceiling = ',h,'):''
read (*,*) zscn
if(zscn.lt.0..or.zscn.gt.h) then
  print *
  print 5,'Input value must be between 0.0 and ',h
5   format (1x,a,f4.1)
  print *, 'Try again.'
  go to 10
endif

C *** PLOT AN X-Z PLANE (a.k.a. Y Section)
elseif(nview.eq.2) then
  iscn=0
  jscn=1
  kscn=0
  xscn=0.
  zscn=0.
20 print *
print 7,
&   'Enter Y distance (in ft) of desired view plane from',
&   'the left wall (Left Wall = 0.0; Right Wall = ',y,'):''
read (*,*) yscn
if(yscn.lt.0..or.yscn.gt.y) then
  print *
  print 5,'Input value must be between 0.0 and ',y
  print *, 'Try again.'
  go to 20
endif

C *** PLOT A Y-Z PLANE (a.k.a. X Section)
elseif(nview.eq.3) then
  iscn=1
  jscn=0
  kscn=0
  yscn=0.
  zscn=0.
30 print *
print 7,
&   'Enter X distance (in ft) of desired view plane from',
&   'the left wall (Left Wall = 0.0; Right Wall = ',x,'):''
read (*,*) xscn
if(xscn.lt.0..or.xscn.gt.x) then
  print *
  print 5,'Input value must be between 0.0 and ',x
  print *, 'Try again.'
  go to 30
endif

C *** ZOOM IN ON A PORTION OF THE LAST PLOT
elseif (nview.eq.4) then

```

```

40      print *
      print *, 'Enter the X & Y coordinates (expressed as a decimal'
      print *, 'percentage of the whole plot, i.e. 25%=0.25) for the '
      print *, 'lower left corner of the area to be enlarged.'
      read (*,*) xfrn1,yfrn1
      if(xfrn1.lt.0..or.xfrn1.gt.1..or.
      &      yfrn1.lt.0..or.yfrn1.gt.1.) then
          print *, 'All coordinates must be between 0.00 and 1.00!'
          print *, 'Please correct and reenter.'
          goto 40
      endif

45      print *
      print *, 'Enter the X & Y coordinates (expressed as a decimal'
      print *, 'percentage of the whole plot, i.e. 25%=0.25) for the '
      print *, 'upper right corner of the area to be enlarged.'
      read (*,*) xfrn2,yfrn2
      if(xfrn2.lt.0..or.xfrn2.gt.1..or.
      &      yfrn2.lt.0..or.yfrn2.gt.1.) then
          print *, 'All coordinates must be between 0.00 and 1.00!'
          print *, 'Please correct and reenter.'
          goto 45
      endif
      if(xfrn2.lt.xfrn1.or.yfrn2.lt.yfrn1) then
          print ('(1x,a,2(f4.2,a))'),
      &          'These coordinates must be greater than ',xfrn1,
      &          ' and ',yfrn1,' respectively.'
          print *, 'Please correct and reenter.'
          goto 45
      endif

C **** ERROR ON ENTRY OF NVIEW
      else
          print *
          print *, 'Incorrect response! Please enter 0 - 4'
          goto 99
      endif

      return
  end
*****
      SUBROUTINE INPUT
*****
      *
      * Input data from existing datafiles.
      *
*****



      implicit real*8 (a-h,o-z)
      common/b11/dx,dy,dz
      common/b12/x,y,h,tflr,twal,ta
      common/b17/ni,nj,nk
      common/data/t(25,25,15),temp(24,24),tt(24,24),xtime,ttmax

C **** READ IN DATA FROM EXISTING DATA FILE
      open(10,file='fire.dat',status='old')

```

```

read(10,*) x,y,h,tflr,twal,ta
read(10,*) ni,nj,nk
rewind 10
close (10)

open (unit=9,file='plot.data',status='unknown')
read(9,1001) xtime,t
1001 format(4(f17.7))
rewind 9
close (9)

C *** DIMENSIONALIZE TEMPERATURES IN DEGRESS CELSIUS
do 77 i=1,ni+4
do 77 j=1,nj+4
do 77 k=1,nk+4
t(I,J,K)=ta*t(i,j,k)/1.8-273.16
77 continue

return
end
*****SUBROUTINE GRID*****
*****implicit real*8 (a-h,o-z)
common/r4/xss(40),yss(40),zss(40),xs(40),ys(40),zs(40)
common/b11/dx,dy,dz
common/b12/x,y,h,tflr,twal,ta
common/b17/ni,nj,nk

C *** GENERATION OF THE GRIDS
dx=x/(float(ni)*h)
dy=y/(float(nj)*h)
dz=h/(float(nk)*h)

C *** CALCULATE XSS,YSS,ZSS (COORDINATES OF STAGGERED CV'S)
do 10 i=3,ni+3
  xss(i)=(i-3)*dx
10 continue
  xss(2)=xss(3)-twal/(h*12.)
  xss(1)=xss(2)-twal/(h*12.)
  xss(ni+4)=xss(ni+3)+twal/(h*12.)
  xss(ni+5)=xss(ni+4)+twal/(h*12.)

  do 12 j=3,nj+3
    yss(j)=(j-3)*dy
12 continue
  yss(2)=yss(3)-twal/(h*12.)
  yss(1)=yss(2)-twal/(h*12.)
  yss(nj+4)=yss(nj+3)+twal/(h*12.)
  yss(nj+5)=yss(nj+4)+twal/(h*12.)

  do 14 k=3,nk+3
    zss(k)=(k-3)*dz
14 continue
  zss(2)=zss(3)-tflr/(h*12.)

```

```

zss(1)=zss(2)-tflr/(h*12.)
zss(nk+4)=zss(nk+3)+tflr/(h*12.)
zss(nk+5)=zss(nk+4)+tflr/(h*12.)

C **** CONVERT TO CENTERED GRID FOR USE BY PROGRAM
do 20 i=1,ni+4
    xs(i)=(xss(i)+xss(i+1))/2
20 continue

do 22 j=1,nj+4
    ys(j)=(yss(j)+yss(j+1))/2
22 continue

do 24 k=1,nk+4
    zs(k)=(zss(k)+zss(k+1))/2
24 continue

return
end
*****
SUBROUTINE INTERPOL
*****
*
* This subroutine interpolates the 3-D section into the desired 2-D
* section. It is a necessary step since any arbitrary section would
* fall in between two grid points and must be linearly interpolated.
*
*****
implicit real*8 (a-h,o-z)
common/lmt1/ixx,jyy
common/lmt2/xx,yy
common/sct1/iscn,jscn,kscn,nview
common/sct2/xscn,yscn,zscn
common/data/t(25,25,15),temp(24,24),tt(24,24),xtime,ttmax
common/r4/xss(40),yss(40),zss(40),xs(40),ys(40),zs(40)
common/b11/dx,dy,dz
common/b12/x,y,h,tflr,twal,ta
common/b17/ni,nj,nk
common/ngs/xxs(40),yys(40)

C **** NONDIMENSIONALIZE NECESSARY VARIABLES
if(nview.ne.4) then
    xscn = xscn / h
    yscn = yscn / h
    zscn = zscn / h
endif
wth = y / h
bth = x / h

C **** LOCATE SECTION OF INTEREST

C **** X SECTION
if (iscn .ne. 0) then
    do 10 i=2,ni+4
        if (xs(i) .ge. xscn .and. xs(i-1) .lt. xscn) then

```

```

        igi = i
    endif
10  continue
    c1 = (xs(igi) - xsxn) / (xs(igi) - xs(igi-1))
    c2 = 1. - c1

c **** INTERPOLATION DONE HERE
    do 20 j=1,nj+4
        do 20 k=1,nk+4
            temp(j,k) = c1 * t(igi-1,j,k) + c2 * t(igi,j,k)
20  continue
    ixx = nj+4
    jyy = nk+4
    xx = wth
    yy = 1.
    do 22 i=1,ixx
        xxs(i) = ys(i)
22  continue
    do 24 j=1,jyy
        yys(j) = zs(j)
24  continue
    endif

C **** Y SECTION
    if (jscn .ne. 0) then
        do 30 j=2,nj+4
            if (ys(j) .ge. yscn .and. ys(j-1) .lt. yscn) then
                jgi = j
            endif
30  continue
        c1 = (ys(jgi) - yscn) / (ys(jgi) - ys(jgi-1))
        c2 = 1. - c1

c **** INTERPOLATION DONE HERE
    do 40 i=1,ni+4
        do 40 k=1,nk+4
            temp(i,k) = c1 * t(i,jgi-1,k) + c2 * t(i,jgi,k)
40  continue
    ixx = ni+4
    jyy = nk+4
    xx = bth
    yy = 1.
    do 42 i=1,ixx
        xxs(i) = xs(i)
42  continue
    do 44 j=1,jyy
        yys(j) = zs(j)
44  continue
    endif

C **** Z SECTION
    if (kscn .ne. 0) then
        do 50 k=2,nk+4
            if (zs(k) .ge. zscn .and. zs(k-1) .lt. zscn) then
                kgi = k
            endif

```

```

50      continue
      c1 = (zs(kgi) - zscn) / (zs(kgi) - zs(kgi-1))
      c2 = 1. - c1

c *** INTERPOLATION DONE HERE
      do 60 i=1,ni+4
          do 60 j=1,nj+4
              temp(i,j) = c1 * t(i,j,kgi-1) + c2 * t(i,j,kgi)
60      continue
      ixx = ni+4
      jyy = nj+4
      xx = bth
      yy = wth
      do 62 i=1,ixx
          xxs(i) = xs(i)
62      continue
      do 64 j=1,jyy
          yys(j) = ys(j)
64      continue
      endif

C *** DETERMINE MAXIMUM TEMPERATURE ON SECTION
      tmax = 0.
      do 70 i=1,ixx
          do 70 j=1,jyy
              if (temp(i,j) .gt. tmax) tmax = temp(i,j)
70      continue
      print *, 'THE MAXIMUM TEMPERATURE IS',tmax

      return
      end
*****
SUBROUTINE SCTN
*****
* In this subroutine the non-uniform grid is interpolated onto a
* uniform grid for plotting purposes. The routine has the option of
* "blowing up" or "zooming in on" a certain portion for detailed
* viewing.
*
*****implicit real*8 (a-h,o-z)
common/data/t(25,25,15),temp(24,24),tt(24,24),xtime,ttmax
common/lmt1/ixx,jyy
common/lmt2/xx,yy
common/r4/xss(40),yss(40),zss(40),xs(40),ys(40),zs(40)
common/ngs/xxs(40),yys(40)
common/ugrd/iplot,jplot,ncremax
common/fctn/xfrn1,xfrn2,yfrn1,yfrn2

c *** DETERMINE LIMITS OF INTERPOLATION
      xlmt1 = xfrn1 * xx
      xlmt2 = xfrn2 * xx
      ylmt1 = yfrn1 * yy
      ylmt2 = yfrn2 * yy

```

```

dx = (xlmt2 - xlmt1) / float(iplot - 1)
dy = (ylmt2 - ylmt1) / float(jplot - 1)

do 20 i=1,iplot
    do 20 j=1,jplot

C *** LOCATE SECTION AND DEVELOP INTERPOLATION PARAMETERS
    - xtmp = xlmt1 + dx * float(i - 1)
    ytmp = ylmt1 + dy * float(j - 1)
    do 10 ii=2,ixx
        if (xxs(ii) .gt. xtmp .and. xxs(ii-1) .lt. xtmp) then
            ii1 = ii
        endif
10    continue
    cx = (xxs(ii1) - xtmp) / (xxs(ii1) - xxs(ii1-1))
    do 15 jj=2,jyy
        if (yys(jj) .gt. ytmp .and. yys(jj-1) .lt. ytmp) then
            jj1 = jj
        endif
15    continue
    cy = (yys(jj1) - ytmp) / (yys(jj1) - yys(jj1-1))
    c11 = cx * cy
    c12 = cx * (1. - cy)
    c21 = (1. - cx) * cy
    c22 = (1. - cx) * (1. - cy)

C *** INTERPOLATION DONE HERE
    tt(i,j) = c11 * temp(ii1-1,jj1-1) + c12 * temp(ii1-1,jj1)
    &           + c21 * temp(ii1,jj1-1) + c22 * temp(ii1,jj1)
20    continue

c *** DETERMINE MAXIMUM INTERPOLATED TEMPERATURE
    ttmax = 0.
    do 30 i=1,iplot
        do 30 j=1,jplot
            if (tt(i,j) .gt. ttmax) ttmax = tt(i,j)
30    continue
    print *, 'THE MAXIMUM INTERPOLATED TEMPERATURE IS', ttmax

    return
end
*****
SUBROUTINE PLOT
*****
*
* This subroutine plots the isotherms using the CONRAN routine of      *
* the NCAR Graphics package.                                         *
*
*****



common/lmt2/xx,yy
common/data/t(25,25,15),temp(24,24),tt(24,24),xtime,ttmax
common/ugrd/iplot,jplot,ncrmax
common/sct1/iscn,jscn,kscn,nview
common/sct2/xscn,yscn,zscn
common/fctn/xfrn1,xfrn2,yfrn1,yfrn2

```

```

common/bl2/x,y,h,tflr,twal,ta
real*8 t,temp,tt,xtime,ttmax,xx,yy,xfrn1,xfrn2,yfrn1,yfrn2
real*8 xscn,yscn,zscn,x,y,h,tflr,twal,ta

dimension zdat(24,24),rwrk(1000),iwrk(1000),iama(120000)
dimension iASF(13)
dimension xcra(1000),ycra(1000)
dimension iaia(10),igia(10)
dimension lind(14)
character*10 llbs(15)
character*5 sec, elev
character*45 title
character*4 x11,x12,y11,y12

c *** DEFINE EXTERNAL SUBROUTINE TO SET COLORS
      external COLRAM

C *** SET PARAMETERS REQUIRED BY NCAR GRAPHICS ROUTINES
      data iASF/13*1/
      data lind/2,3,4,5,6,7,8,9,10,11,12,13,14,15/

***** CONVERT TO SINGLE PRECISION (NCAR WON'T WORK IN DOUBLE PRECISION) *****
C *** FIRE TIME WHEN DATA WAS TAKEN
      time=xtime*h/1.0

C *** SECTION TO PLOT
      if(iscn.gt.0) then
        scn=xscn*h
        xzoom1=xfrn1*y
        xzoom2=xfrn2*y
        yzoom1=yfrn1*h
        yzoom2=yfrn2*h
      elseif(jscn.gt.0) then
        scn=yscn*h
        xzoom1=xfrn1*x
        xzoom2=xfrn2*x
        yzoom1=yfrn1*h
        yzoom2=yfrn2*h
      else
        scn=zscn*h
        xzoom1=xfrn1*x
        xzoom2=xfrn2*x
        yzoom1=yfrn1*y
        yzoom2=yfrn2*y
      endif

C *** SET VERTICAL DIMENSION OF OUTPUT DISPLAY
c      if(iscn.gt.0.or.jscn.gt.0) then
c        ndim=14
c      else
c        ndim=24
c      endif

c *** DETERMINE MAX AND MIN TEMPS FOR ENTIRE 3-D GRID
      cmax = -2.0e20
      cmin = 2.0e20

```

```

do 10 i=1,24
  do 10 j=1,24
    do 10 k=1,14
      if(t(i,j,k).gt.cmax) cmax = t(i,j,k)
      if(t(i,j,k).lt.cmin) cmin = t(i,j,k)
10  continue

  do 20 i=1,iplot
    do 20 j=1,jplot
      zdat(i,j) = tt(i,j)
20  continue

c **** CALCULATE THE SPACINGS BETWEEN CONTOURS
dc=(cmax-cmin)/real(ncrmax-1)

***** RUN NCAR GRAPHICS PACKAGE *****
C *** START NCAR GRAPHICS
call GOPKS (6,0)
call GOPWK (1,2,1)
call GACWK (1)

C *** TURN OFF CLIPPING SO WORDS WILL PLOT
call GSCLIP (0)
call GSASF  (iasf)
call GSFAIS (1)

C *** DEFINE COLORS
call DFCLRS

C *** DEFINE VIEWPORT AND PLOT CONTOURS
call CPSETR ('VPS - VIEWPORT SHAPE',0)
if(kscn.gt.0) then
  call CPSETR ('VPB - VIEWPORT BOTTOM',.15)
  call CPSETR ('VPT - VIEWPORT TOP',.95)
else
  call CPSETR ('VPB - VIEWPORT BOTTOM',.25)
  call CPSETR ('VPT - VIEWPORT TOP',.65)
endif
call CPSETR ('VPL - VIEWPORT LEFT',.1)
call CPSETR ('VPR - VIEWPORT RIGHT',.9)
call CPSETI ('NOF - NUMERIC OMISSION FLAGS',0)
call CPSETI ('CLS - CONTOUR LEVEL SELECTOR',NCRMAX)
call CPSETR ('CIS - CONTOUR INTERVAL SPECIFIER',dc)
call CPSETI ('LLP - LINE LABEL POSITIONING',0)
call CPSETR ('CMN - CONTOUR MINIMUM',cmin)
call CPSETR ('CMX - CONTOUR MAXIMUM',cmax)
call CPRECT (zdat,24,24,ndim,rwrk,1000,iwrk,1000)
call ARINAM (iama,120000)
call CPCLAM (zdat,rwrk,iwrk,iama)
call ARSCAM (iama,xcra,ycra,1000,iaia,igia,10,COLRAM)
call GSPLCI (0)
call CPCLDR (zdat,rwrk,iwrk)
call GSPLCI (1)

c *** CONVERT REAL VARIABLES TO CHARACTER VARIABLES FOR PLOTTING
C *** AND SET COLORS FOR PLOTTING

```

```

call CPGETI ('NCL - NUMBER OF CONTOUR LEVELS',ncl)
do 102 i=1,ncl
  call CPSETI ('PAI - PARAMETER ARRAY INDEX',i)
  call CPSETI ('AIA - AREA IDENTIFIER ABOVE',i)
  call CPSETI ('AIB - AREA IDENTIFIER BELOW',i-1)
  call CPGETR ('CLV - CONTOUR LEVEL VALUES',zlbs)
  call CPSETR ('ZDV - Z DATA VALUE',zlbs)
  call CPGETC ('ZDV - Z DATA VALUE',llbs(i))
102 continue

  call CPSETR ('ZDV - Z DATA VALUE',time)
  call CPGETC ('ZDV - Z DATA VALUE',sec)

  call CPSETR ('ZDV - Z DATA VALUE',scn)
  call CPGETC ('ZDV - Z DATA VALUE',elev)

  call CPSETR ('ZDV - Z DATA VALUE',xzoom1)
  call CPGETC ('ZDV - Z DATA VALUE',x11)

  call CPSETR ('ZDV - Z DATA VALUE',xzoom2)
  call CPGETC ('ZDV - Z DATA VALUE',x12)

  call CPSETR ('ZDV - Z DATA VALUE',yzoom1)
  call CPGETC ('ZDV - Z DATA VALUE',y11)

  call CPSETR ('ZDV - Z DATA VALUE',yzoom2)
  call CPGETC ('ZDV - Z DATA VALUE',y12)

c **** CONSTRUCT LABEL BAR
call LBSETI ('CBL - COLOR OF BOX LINES',0)
if(kscn.gt.0) then
  call LBLBAR (0,.05,.95,.05,.10,14,1.,.5,lind,0,llbs,15,1)
else
  call LBLBAR (0,.05,.95,.15,.20,14,1.,.5,lind,0,llbs,15,1)
endif

***** LABEL AXIS AND TITLE PLOT *****
c *** X SECTION
if(iscn.gt.0) then
  title='Y-Z PROFILE (X = //elev//' FT.) AT '//sec//'' SEC.'
  call PLCHHQ(3.,25.,title,.015,0.,-1.)
  call PLCHHQ(9.,-6.,'TEMPERATURE (CELSIUS)',.01,0.,-1.)
  call PLCHHQ(10.,0.,'BREADTH (Y-DIR)',.01,0.,-1.)
  call PLCHHQ(1.,0.,x11,.01,0.,-1.)
  call PLCHHQ(23.,0.,x12,.01,0.,-1.)
  call PLCHHQ(.5,11.0,'HEIGHT (Z-DIR)',.01,90.,0.)
  call PLCHHQ(.5,1.5,y11,.01,90.,0.)
  call PLCHHQ(.5,23.,y12,.01,90.,0.)

c *** Y SECTION
elseif(jscn.gt.0) then
  title='X-Z PROFILE (Y = //elev//' FT.) AT '//sec//'' SEC.'
  call PLCHHQ(3.,25.,title,.015,0.,-1.)
  call PLCHHQ(9.,-6.,'TEMPERATURE (CELSIUS)',.01,0.,-1.)
  call PLCHHQ(10.,0.,'DEPTH (X-DIR)',.01,0.,-1.)
  call PLCHHQ(1.,0.,x11,.01,0.,-1.)

```

```

call PLCHHQ(23.,0.,x12,.01,0.,-1.)
call PLCHHQ(.5,11.0,'HEIGHT (Z-DIR)',.01,90.,0.)
call PLCHHQ(.5,1.5,y11,.01,90.,0.)
call PLCHHQ(.5,23.,y12,.01,90.,0.)

C *** Z SECTION
elseif(kscn.gt.0) then
  title='PLAN VIEW (Z = //elev// FT.) AT //sec// SEC.'
  call PLCHHQ(3.5,24.5,title,.015,0.,-1.)
  call PLCHHQ(8.,-2.5,'TEMPERATURE (CELSIUS)',.01,0.,-1.)
  call PLCHHQ(10.,.5,'DEPTH (X-DIR)',.01,0.,-1.)
  call PLCHHQ(1.,.5,x11,.01,0.,-1.)
  call PLCHHQ(23.,.5,x12,.01,0.,-1.)
  call PLCHHQ(.5,9.0,'BREADTH (Y-DIR)',.01,90.,-1.)
  call PLCHHQ(.5,1.5,y11,.01,90.,0.)
  call PLCHHQ(.5,23.5,y12,.01,90.,0.)
endif

C *** DRAW BOUNDARY AROUND VIEWPORT
call BNDARY

c *** ADVANCE FRAME FOR NEXT PLOT
call FRAME

C *** FINISHED WITH NCAR GRAPHICS
call GCLRWK (1,1)
call GDAWK (1)
call GCLWK (1)
call GCLKS

      return
end
*****
SUBROUTINE DFCLRS
*****
*
* Define colors using Red-Green-Blue (RGB) triples.
*
*****
dimension rgbv(3,15)
data rgbv/ 0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.00,0.70,
&          0.00,0.00,1.00,0.00,0.50,0.75,0.00,0.75,0.50,
&          0.00,1.00,0.00,0.65,1.00,0.00,1.00,1.00,0.00,
&          1.00,0.75,0.00,1.00,0.50,0.00,1.00,0.00,0.00,
&          1.00,0.10,0.40,1.00,0.40,0.70,1.00,0.70,1.00/

c *** DEFINE DEFAULT BACKGROUND COLOR AS WHITE
call GSCR (1,0,1.,1.,1.)
c
C *** DEFINE REMAINING COLORS
C *** (NOTE: i=1 is default foreground color and is set to black)
do 101 i=1,15
  call GSCR (1,i,rgbv(1,i),rgbv(2,i),rgbv(3,i))
101 continue

```

```

    return
  end
*****
 SUBROUTINE COLRAM (xcra,ycra,ncra,iaia,igia,naia)
*****
*
* This subroutine is used by NCAR GRAPHICS (call DEFCLRS) to assign *
* the colors to the contour levels. It must be declared EXTERNAL      *
* before any calls are made to any NCAR subroutines.                  *
*
*****
 dimension xcra(*),ycra(*),iaia(*),igia(*)
 ifll = 1

  do 101 i=1,naia
    if (iaia(i) .lt. 0) ifll = 0
101 continue
  if (ifll .ne. 0) then
    ifll = 0
    do 102 i=1,naia
      if (igia(i) .eq. 3) ifll = iaia(i)
102 continue
  if (ifll .gt. 0 .and. ifll .lt. 15) then
    call GSFACI (ifll)
    call GFA (ncra-1,xcra,ycra)
  endif
  endif

  return
end
*****
 SUBROUTINE BNDARY
*****
*
* This subroutine defines the edge of the plot frame and draws a line *
* at its location.
*
*****
 call PLOTIF (0.,0.,0)
 call PLOTIF (1.,0.,1)
 call PLOTIF (1.,1.,1)
 call PLOTIF (0.,1.,1)
 call PLOTIF (0.,0.,1)
 call PLOTIF (0.,0.,2)

  return
end

```

## APPENDIX D. PROGRAM VELOCITY

This program plots two dimensional velocity profiles, using the National Center for Atmospheric Research (NCAR) Graphics software, from the three dimensional velocity field generated by the program FIRE.

### PROGRAM VELOCITY

```
*****
* This program uses NCAR GRAPHICS to calculate and plot velocity
* vectors in an arbitrary two dimensional section with uniform grid
* spacing from a non-uniform three dimensional grid using linear
* interpolation routines.
*****
*Variables:
* nstop  : Control variable to end program
* xscn   : X location where Y-Z plane to be taken
* yscn   : Y location where X-Z plane to be taken
* zscn   : Z location where X-Y plane to be taken
* iscn   : If >0 hold X constant, else =0
* jscn   : If >0 hold Y constant, else =0
* kscn   : If >0 hold Z constant, else =0
* xfrn1  : Starting 2-D, X coordinate of section to zoom in on
* xfrn2  : Ending 2-D, X coordinate of section to zoom in on
* yfrn1  : Starting 2-D, Y coordinate of section to zoom in on
* yfrn2  : Ending 2-D, Y coordinate of section to zoom in on
* t()     : Dummy variable necessary due to format of input datafile
* u()     : Non-dimensional input value of X component of velocity
* v()     : Non-dimensional input value of Y component of velocity
* w()     : Non-dimensional input value of Z component of velocity
* iplot   : Number of grids in X direction of 2-D grid
* jplot   : Number of grids in Y direction of 2-D grid
* x       : Non-dimensional X length of compartment to model
* y       : Non-dimensional Y length of compartment to model
* h       : Non-dimensional Z length of compartment to model
* tflr   : Non-dimensional thickness of compartment floor/ceiling
* twal   : Non-dimensional thickness of compartment walls
* ta     : Non-dimensional ambient temperature
* dx     : Non-dimensional 3-D grid size inside compartment, X dir.
* dy     : Non-dimensional 3-D grid size inside compartment, Y dir.
* dz     : Non-dimensional 3-D grid size inside compartment, Z dir.
* ni     : Number of cells across compartment, X dir.
* nj     : Number of cells across compartment, Y dir.
* nk     : Number of cells across compartment, Z dir.
* nview  : Input value of desired plot (from SUBROUTINE SECTION)
*****
```

C \*\*\* READ IN DATA GENERATED BY PROGRAM "FIRE"

```

call INPUT

C *** GENERATE GRID
call GRID

C *** DEFINE DESIRED SECTION
5 call SECTION(nstop)

C *** CHECK IF FINISHED WITH PROGRAM
if (nstop.gt.0) goto 9999

C *** LOCATE DESIRED SECTION
call INTERPOL

C *** INTERPOLATE TO A 2-D PLOT
call SCTN

C *** GENERATE VELOCITY VECTOR PLOT USING NCAR GRAPHICS
call PLOT

C *** LOOP BACK FOR ANOTHER SECTION
goto 5

C *** FINISHED WITH PROGRAM
9999 end
*****
      BLOCK DATA
*****
*
*   The variables IPLOT and JPLOT define the number of uniformly spaced *
*   grids to be used in generating the 2-D plot and must be changed if   *
*   a different grid spacing is desired.                               *
*
*****
implicit real*8 (a-h,o-z)
common/ugrd/iplot,jplot
common/sctl/iscn,jscn,kscn,nview

data iplot,jplot/24,24/
data nview/0/

end
*****
      SUBROUTINE INPUT
*****
*
*   Input data from existing datafiles.                               *
*
*****
implicit real*8 (a-h,o-z)
common/bl1/dx,dy,dz
common/bl2/x,y,h,tflr,twal,ta,xtime
common/bl7/ni,nj,nk
common/data/t(25,25,15),u(25,25,15),v(25,25,15),w(25,25,15),

```

```

& uu(24,24),vv(24,24),uu1(24,24),vv1(24,24)

C *** READ IN DATA FROM EXISTING DATA FILE
open(10,file='fire.dat',status='old')
read(10,*) x,y,h,tflr,twal,ta
read(10,*) ni,nj,nk
rewind 10
close (10)

open (unit=9,file='plot.data',status='unknown')
read(9,1000) xtime,t,u,v,w
1000 format(4(f17.7))

C *** DIMENSIONALIZE VELOCITIES TO CM/SEC
do 10 i=1,ni+4
  do 10 j=1,nj+4
    do 10 k=1,nk+4
      u(i,j,k)=u(i,j,k)*30.25
      v(i,j,k)=v(i,j,k)*30.25
      w(i,j,k)=w(i,j,k)*30.25
10 continue

return
end
*****SUBROUTINE GRID*****
*****SUBROUTINE GRID*****
```

```

implicit real*8 (a-h,o-z)
common/r4/xss(40),yss(40),zss(40),xs(40),ys(40),zs(40)
common/bl1/dx,dy,dz
common/bl2/x,y,h,tflr,twal,ta,xtime
common/bl7/ni,nj,nk

C *** GENERATION OF THE GRIDS
dx=x/(float(ni)*h)
dy=y/(float(nj)*h)
dz=h/(float(nk)*h)

C *** CALCULATE XSS,YSS,ZSS (COORDINATES OF STAGGERED CV'S)
do 10 i=3,ni+3
  xss(i)=(i-3)*dx
10 continue
xss(2)=xss(3)-twal/(h*12.)
xss(1)=xss(2)-twal/(h*12.)
xss(ni+4)=xss(ni+3)+twal/(h*12.)
xss(ni+5)=xss(ni+4)+twal/(h*12.)

do 12 j=3,nj+3
  yss(j)=(j-3)*dy
12 continue
yss(2)=yss(3)-twal/(h*12.)
yss(1)=yss(2)-twal/(h*12.)
yss(nj+4)=yss(nj+3)+twal/(h*12.)
yss(nj+5)=yss(nj+4)+twal/(h*12.)
```

```

do 14 k=3,nk+3
  zss(k)=(k-3)*dz
14 continue
  zss(2)=zss(3)-tflr/(h*12.)
  zss(1)=zss(2)-tflr/(h*12.)
  zss(nk+4)=zss(nk+3)+tflr/(h*12.)
  zss(nk+5)=zss(nk+4)+tflr/(h*12.)

C *** CONVERT TO CENTERED GRID FOR USE BY PROGRAM
  do 20 i=1,ni+4
    xs(i)=(xss(i)+xss(i+1))/2
20 continue

  do 22 j=1,nj+4
    ys(j)=(yss(j)+yss(j+1))/2
22 continue

  do 24 k=1,nk+4
    zs(k)=(zss(k)+zss(k+1))/2
24 continue

  return
end
*****
SUBROUTINE SECTION(nstop)
*****
```

```

implicit real*8 (a-h,o-z)
common/fctn/xfrn1,xfrn2,yfrn1,yfrn2
common/sct1/iscn,jscn,kscn,nview
common/sct2/xscn,yscn,zscn
common/b12/x,y,h,tflr,twal,ta,xtime

99 print *
print *
print *, 'ENTER    FOR:'
print *, '-----  -----'
print *, '  0    Finished with program'
print *, '  1    Plan View (X-Y plane)'
print *, '  2    Elevation (X-Z plane)'
print *, '  3    Elevation (Y-Z plane)'
if(nview.le.0) goto 97
print *, '  4    Enlargement of portion of previous plot'
97 print *
print *, 'Enter your desired vector field plot:'
read (*,*) nview
nstop=0
xfrn1=0.
xfrn2=1.
yfrn1=0.
yfrn2=1.

C *** END PROGRAM
if (nview.eq.0) then
  nstop=9999
```

```

C *** PLOT AN X-Y PLANE (aka Z SECTION)
  elseif (nview.eq.1) then
    iscn=0
    jscn=0
    kscn=1
    xscn=0.
    yscn=0.
10   print *
7    format (1x,a/1x,a,f5.2,a)
    print 7,
&      'Enter desired height of desired plot above the floor',
&      '(Floor = 0.0; Ceiling = ',h,)'
    read (*,*) zscn
    if(zscn.lt.0..or.zscn.gt.h) then
      print *
      print 5,'Input value must be between 0.0 and ',h
5     format (1x,a,f4.1)
      print *, 'Try again.'
      go to 10
    endif

C *** PLOT AN X-Z PLANE (aka Y SECTION)
  elseif (nview.eq.2) then
    iscn=0
    jscn=1
    kscn=0
    xscn=0.
    zscn=0.
20   print *
    print 7,
&      'Enter Y distance (in ft) of desired plot from the left wall',
&      '(Left Wall = 0.0; Right Wall = ',y,)'
    read (*,*) yscn
    if(yscn.lt.0..or.yscn.gt.y) then
      print *
      print 5,'Input value must be between 0.0 and ',y
      print *, 'Try again.'
      go to 20
    endif

C *** PLOT A Y-Z PLANE (aka X SECTION)
  elseif (nview.eq.3) then
    iscn=1
    jscn=0
    kscn=0
    zscn=0.
    yscn=0.
30   print *
    print 7,
&      'Enter X distance (in ft) of desired plot from the right wall',
&      '(Left Wall = 0.0; Right Wall = ',x,)'
    read (*,*) xscn
    if(xscn.lt.0..or.xscn.gt.x) then
      print *
      print 5,'Input value must be between 0.0 and ',x

```

```

        print *, 'Try again.'
        go to 30
    endif

C *** ZOOM IN ON A PORTION OF THE LAST PLOT
    elseif (nview.eq.4) then
40    print *
        print *, 'Enter the X & Y coordinates (expressed as a decimal'
        print *, 'percentage of the whole plot, i.e. 25%=0.25) for the '
        print *, 'lower left corner of the area to be enlarged.'
        read (*,*) xfrn1,yfrn1
        if(xfrn1.lt.0..or.xfrn1.gt.1..or.
&           yfrn1.lt.0..or.yfrn1.gt.1.) then
            print *, 'All coordinates must be between 0.00 and 1.00!'
            print *, 'Please correct and reenter.'
            goto 40
        endif

45    print *
        print *, 'Enter the X & Y coordinates (expressed as a decimal'
        print *, 'percentage of the whole plot, i.e. 25%=0.25) for the '
        print *, 'upper right corner of the area to be enlarged.'
        read (*,*) xfrn2,yfrn2
        if(xfrn2.lt.0..or.xfrn2.gt.1..or.
&           yfrn2.lt.0..or.yfrn2.gt.1.) then
            print *, 'All coordinates must be between 0.00 and 1.00!'
            print *, 'Please correct and reenter.'
            goto 45
        endif
        if(xfrn2.lt.xfrn1.or.yfrn2.lt.yfrn1) then
            print ('(1x,a,2(f4.2,a))'),
&                 'These coordinates must be greater than ',xfrn1,
&                 ' and ',yfrn1,' respectively.'
            print *, 'Please correct and reenter.'
            goto 45
        endif

```

```

C *** ERROR ON ENTRY OF NVIEW
    else
        print *
        print *, 'Incorrect response! Please enter 0 - 4'
        goto 99
    endif

    return
end

```

```
*****
SUBROUTINE INTERPOL
*****
*
* This subroutine interpolates to the desired section. It is
* necessary since any arbitrary section would fall in between two
* grid points and must be linearly interpolated.
*
*****
```

```

implicit real*8 (a-h,o-z)
common/data/t(25,25,15),u(25,25,15),v(25,25,15),w(25,25,15),
& uu(24,24),vv(24,24),uu1(24,24),vv1(24,24)
common/lmt1/ixx,jyy
common/lmt2/xx,yy
common/sct1/iscn,jscn,kscn,nview
common/ngs/xxs(40),yys(40),x1(40),y1(40)
common/r4/xss(40),yss(40),zss(40),xs(40),ys(40),zs(40)
common/bl1/dx,dy,dz
common/sct2/xscn,yscn,zscn
common/bl2/x,y,h,tflr,twal,ta,xtime
common/bl7/ni,nj,nk

C *** NON-DIMENSIONALIZE REQUIRED VARIABLES
if(nview.ne.4) then
  xscn = xscn / h
  yscn = yscn / h
  zscn = zscn / h
endif
wth = y / h
bth = x / h

***** LOCATE SECTION OF INTEREST *****

C *** X SECTION
if (iscn .ne. 0) then
  do 10 i=2,ni+4
    if (xs(i) .ge. xscn .and. xs(i-1) .lt. xscn) then
      igi = i
    endif
10  continue
  c1 = (xs(igi) - xscn) / (xs(igi) - xs(igi-1))
  c2 = 1. - c1

C *** INTERPOLATION DONE HERE
do 20 j=2,nj+4
  do 20 k=2,nk+4
    vv(j,k) = c1 * w(igi-1,j,k) + c2 * w(igi,j,k)
    uu(j,k) = c1 * v(igi-1,j,k) + c2 * v(igi,j,k)
20  continue
  ixx = nj+4
  jyy = nk+4
  xx = wth
  yy = 1.
  do 22 i=1,ixx
    xxs(i) = ys(i)
    x1(i) = yss(i)
22  continue
  do 24 j=1,jyy
    yys(j) = zs(j)
    y1(j) = zss(j)
24  continue
endif

C *** Y SECTION

```

```

        if (jscn .ne. 0) then
            do 30 j=2,nj+4
                if (ys(j) .ge. yscn .and. ys(j-1) .lt. yscn) then
                    jgi = j
                endif
30        continue
            c1 = (ys(jgi) - yscn) / (ys(jgi) - ys(jgi-1))
            c2 = 1. - c1

C *** INTERPOLATION DONE HERE
        do 40 i=2,ni+4
            do 40 k=2,nk+4
                uu(i,k) = c1 * u(i,jgi-1,k) + c2 * u(i,jgi,k)
                vv(i,k) = c1 * w(i,jgi-1,k) + c2 * w(i,jgi,k)
40        continue
        ixx = ni+4
        jyy = nk+4
        xx = bth
        yy = 1.
        do 42 i=1,ixx
            xxs(i) = xs(i)
            x1(i) = xss(i)
42        continue
        do 44 j=1,jyy
            yys(j) = zs(j)
            y1(j) = zss(j)
44        continue
    endif

C *** Z SECTION
        if (kscn .ne. 0) then
            do 50 k=2,nk+4
                if (zs(k) .ge. zscn .and. zs(k-1) .lt. zscn) then
                    kgi = k
                endif
50        continue
            c1 = (zs(kgi) - zscn) / (zs(kgi) - zs(kgi-1))
            c2 = 1. - c1

C *** INTERPOLATION DONE HERE
        do 60 i=2,ni+4
            do 60 j=2,nj+4
                uu(i,j) = c1 * u(i,j,kgi-1) + c2 * u(i,j,kgi)
                vv(i,j) = c1 * v(i,j,kgi-1) + c2 * v(i,j,kgi)
60        continue
        ixx = ni+4
        jyy = nj+4
        xx = bth
        yy = wth
        do 62 i=1,ixx
            xxs(i) = xs(i)
            x1(i) = xss(i)
62        continue
        do 64 j=1,jyy
            yys(j) = ys(j)
            y1(j) = yss(j)

```

```

64      continue
      endif

C *** DETERMINE MAXIMUM VELOCITY COMPONENTS
      cx = 0.
      cy = 0.
      do 70 i=1,ixx
          do 70 j=1,jyy
              if (abs(uu(i,j)) .gt. cx) cx = abs(uu(i,j))
              if (abs(vv(i,j)) .gt. cy) cy = abs(vv(i,j))
70  continue
      print *, 'THE MAXIMUM X-DIRECTION VELOCITY IS',cx
      print *, 'THE MAXIMUM Y-DIRECTION VELOCITY IS',cy

      return
      end
*****
SUBROUTINE SCTN
*****
*
*
* In this subroutine the non-uniform grid is interpolated onto a
* uniform grid for plotting purposes. The routine has the option of
* "blowing up" or "zooming in on" a certain portion for detailed
* viewing.
*
*****
implicit real*8 (a-h,o-z)
common/data/t(25,25,15),u(25,25,15),v(25,25,15),w(25,25,15),
&           uu(24,24),vv(24,24),uul(24,24),vvl(24,24)
common/lmt1/ixx,jyy
common/lmt2/xx,yy
common/r4/xss(40),yss(40),zss(40),xs(40),ys(40),zs(40)
common/ngs/xxs(40),yys(40),x1(40),y1(40)
common/ugrd/iplot,jplot
common/fctn/xfrn1,xfrn2,yfrn1,yfrn2

C *** DETERMINE LIMITS OF INTERPOLATION
x1mt1 = xfrn1 * xx
x1mt2 = xfrn2 * xx
y1mt1 = yfrn1 * yy
y1mt2 = yfrn2 * yy
dx = (x1mt2 - x1mt1) / float(iplot - 1)
dy = (y1mt2 - y1mt1) / float(jplot - 1)

C *** LOCATE SECTION AND DEVELOP INTERPOLATION PARAMETERS
do 20 i=1,iplot
    do 20 j=1,jplot
        xtmp = x1mt1 + dx * float(i - 1)
        ytmp = y1mt1 + dy * float(j - 1)
        do 10 ii=2,ixx
            if (xss(ii) .ge. xtmp .and. xss(ii-1) .lt. xtmp) then
                i11 = ii
            endif
            if (x1(ii) .ge. xtmp .and. x1(ii-1) .lt. xtmp) then

```

```

        ii2 = ii
    endif
10    continue
    cx = (xxs(ii1) - xtmp) / (xxs(ii1) - xxs(ii1-1))
    cx_s = (x1(ii2) - xtmp) / (x1(ii2) - x1(ii2-1))
    do 15 jj=2,jyy
        if (yys(jj) .ge. ytmp .and. yys(jj-1) .lt. ytmp) then
            jj1 = jj
        endif
        if (y1(jj) .ge. ytmp .and. y1(jj-1) .lt. ytmp) then
            jj2 = jj
        endif
    15    continue
    cy = (yys(jj1) - ytmp) / (yys(jj1) - yys(jj1-1))
    cy_s = (y1(jj2) - ytmp) / (y1(jj2) - y1(jj2-1))

    c11_u = cx_s * cy
    c12_u = cx_s * (1. - cy)
    c21_u = (1. - cx_s) * cy
    c22_u = (1. - cx_s) * (1. - cy)

    c11_v = cx * cy_s
    c12_v = cx * (1. - cy_s)
    c21_v = (1. - cx) * cy_s
    c22_v = (1. - cx) * (1. - cy_s)

C **** INTERPOLATION DONE HERE
    uul(i,j) = c11_u * uu(ii2-1,jj1-1) + c12_u * uu(ii2-1,jj1)
    &           + c21_u * uu(ii2,jj1-1) + c22_u * uu(ii2,jj1)
    &           + c11_v * vv(ii1-1,jj2-1) + c12_v * vv(ii1-1,jj2)
    &           + c21_v * vv(ii1,jj2-1) + c22_v * vv(ii1,jj2)
20    continue

C **** DETERMINE MAXIMUM INTERPOLATED SPEED
    vmax = 0.
    do 30 i=1,iplot
        do 30 j=1,jplot
            vmag = sqrt(uul(i,j)**2 + vv1(i,j)**2)
            if (vmag .gt. vmax) vmax = vmag
30    continue
    print *, 'THE MAXIMUM SPEED IS',vmax

C **** DETERMINE MAXIMUM INTERPOLATED VELOCITY COMPONENTS
    umax = 0.
    vmax = 0.
    do 40 i=1,iplot
        do 40 j=1,jplot
            if (abs(uul(i,j)) .gt. umax) umax = abs(uul(i,j))
            if (abs(vv1(i,j)) .gt. vmax) vmax = abs(vv1(i,j))
40    continue
    print *, 'MAXIMUM INTERPOLATED U-VEL',umax
    print *, 'MAXIMUM INTERPOLATED V-VEL',vmax

    return
    end
*****

```

```

SUBROUTINE PLOT
*****
* This subroutine plots the velocity vectors using the VELVCT routine *
* of the NCAR Graphics package. *
*****
common/data/t(25,25,15),u(25,25,15),v(25,25,15),w(25,25,15),
& uu(24,24),vv(24,24),uu1(24,24),vv1(24,24)
common/lmt2/xx,yy
common/ugrd/iplot,jplot
common/sct1/iscn,jscn,kscn,nview
common/sct2/xscn,yscn,zscn
common/b12/x,y,h,tflr,twal,ta,xtime
common/fctn/xfrn1,xfrn2,yfrn1,yfrn2

external TAG

real*8 t,u,v,w,uu,vv,uu1,vv1,xx,yy
real*8 xscn,yscn,zscn,x,y,h,tflr,twal,ta,xtime
real*8 xfrn1,xfrn2,yfrn1,yfrn2
character*5 elev,sec
character*45 title
character*4 x11,x12,y11,y12

dimension varx(24,24),vary(24,24),spv(2)

C *** SET PARAMETERS REQUIRED FOR NCAR GRAPHICS ROUTINES
data spv/2*0./

***** CONVERT TO SINGLE PRECISION (NCAR WON'T WORK IN DOUBLE PRECISION) *****

C *** FIRE TIME WHEN DATA WAS TAKEN
time=xtime*h/1.0

C *** SECTION TO PLOT
if(iscn.gt.0) then
  scn=xscn*h
  xzoom1=xfrn1*y
  xzoom2=xfrn2*y
  yzoom1=yfrn1*h
  yzoom2=yfrn2*h
elseif(jscn.gt.0) then
  scn=yscn*h
  xzoom1=xfrn1*x
  xzoom2=xfrn2*x
  yzoom1=yfrn1*h
  yzoom2=yfrn2*h
else
  scn=zscn*h
  xzoom1=xfrn1*x
  xzoom2=xfrn2*x
  yzoom1=yfrn1*y
  yzoom2=yfrn2*y
endif

```

```

C *** CONVERT REAL NUMBERS TO CHARACTERS FOR USE IN TITLE
  call TAG(scn,elev)
  call TAG(time,sec)
  call TAG(xzoom1,x11)
  call TAG(xzoom2,x12)
  call TAG(yzoom1,y11)
  call TAG(yzoom2,y12)

C *** DEFINE DIMENSIONS OF PLOT AREA
  xlft = 0.125
  xrgt = xlft + 0.75*xx/2.
  ybot = 0.20
  ytop = ybot + 0.75*yy/2.
  x1 = 24.
  if (kscn.gt.0) then
    y1 = 24.
  else
    y1 = 14.
  endif

C *** VELOCITY COMPONENTS
  do 20 i=1,iplot
    do 20 j=1,jplot
      varx(i,j) = uul(i,j)
      vary(i,j) = vvl(i,j)
20  continue

C *** START WITH NCAR GRAPHICS
  call GOPKS (6,0)
  call GOPWK (1,2,1)
  call GACWK (1)

C *** TURN OFF CLIPPING SO CHARACTERS ARE PRINTED OUTSIDE PLOT
  call GSCLIP(0)

C *** DEFINE BOUNDARIES AND SET PERIMETER FOR VECTOR PLOT
  call SET (xlft,xrgt,ybot,ytop,1.,x1,1.,y1,1)
  call PERIM (1,0,1,0)

C *** PLOT VELOCITY VECTORS
  call VELVCT (varx,iplot,vary,iplot,iplot,jplot,0.,0.,-1,0,0,spv)

***** LABEL AXIS AND TITLE PLOT *****
C *** X SECTION
  if(iscn.gt.0) then
    title='Y-Z ELEVATION (X = //elev// FT.) AT //sec// SEC.'
    call PLCHHQ((xlft+xrgt)/2.+.75,ybot-2.5,title,.015,0.,-1.)
    call PLCHHQ(10.,.5,'BREADTH (Y-DIR)',.01,0.,-1.)
    call PLCHHQ(1.,.5,x11,.01,0.,-1.)
    call PLCHHQ(23.,.5,x12,.01,0.,-1.)
    call PLCHHQ(.5,7.0,'HEIGHT (Z-DIR)',.01,90.,0.)
    call PLCHHQ(.5,1.5,y11,.01,90.,0.)
    call PLCHHQ(.5,13.5,y12,.01,90.,0.)

```

```

C *** Y SECTION
elseif(jscn.gt.0) then
  title='X-Z ELEVATION (Y = '//elev//' FT.) AT '//sec//' SEC.'
  call PLCHHQ((x1ft+xrgt)/2.+.75,ybot-2.5,title,.015,0.,-1.)
  call PLCHHQ(10.,.5,'DEPTH (X-DIR)',.01,0.,-1.)
  call PLCHHQ(1.,.5,x11,.01,0.,-1.)
  call PLCHHQ(23.,.5,x12,.01,0.,-1.)
  call PLCHHQ(.5,7.0,'HEIGHT (Z-DIR)',.01,90.,0.)
  call PLCHHQ(.5,1.5,y11,.01,90.,0.)
  call PLCHHQ(.5,13.5,y12,.01,90.,0.)

C *** Z SECTION
elseif(kscn.gt.0) then
  title='PLAN VIEW (Z = '//elev//' FT.) AT '//sec//' SEC.'
  call PLCHHQ((x1ft+xrgt)/2.+1.5,ybot-2.5,title,.015,0.,-1.)
  call PLCHHQ(10.,.5,'DEPTH (X-DIR)',.01,0.,-1.)
  call PLCHHQ(1.,.5,x11,.01,0.,-1.)
  call PLCHHQ(23.,.5,x12,.01,0.,-1.)
  call PLCHHQ(.5,9.0,'BREADTH (Y-DIR)',.01,90.,-1.)
  call PLCHHQ(.5,1.5,y11,.01,90.,0.)
  call PLCHHQ(.5,23.5,y12,.01,90.,0.)
endif

C *** FINISHED WITH NCAR GRAPHICS
call GCLRWK (1,1)
call GDAWK (1)
call GCLWK (1)
call GCLKS

return
end
*****
SUBROUTINE TAG(scn,elev)
*****
*
* This subroutine converts scn to a character value for use in the
* title of the plot.
*
*****
character*1 e(0:9)
character*5 elev

data e/'0','1','2','3','4',
&      '5','6','7','8','9'/

if(scn.ge.100..and.scn.lt.1000.) then
  i1=int(scn/100.)
  i2=int((scn-real(i1)*100.)/10.)
  i3=int(scn-(real(i1)*100.+real(i2)*10))
  i4=nint((scn*10.-int(scn*10.))*10.)
  elev=e(i1)//e(i2)//e(i3)//'.'//e(i4)
elseif(scn.ge.10..and.scn.lt.100.) then
  i1=int(scn/10.)
  i2=int(scn-real(i1)*10.)

```

```
i3=int((scn-int(scn))*10.)
i4=nint((scn*10.-int(scn*10.))*10.)
elev=e(i1)//e(i2)//'.'//e(i3)//e(i4)
elseif(scn.lt.10) then
  i1=int(scn)
  i2=int((scn-int(scn))*10.)
  i3=int((scn*10.-int(scn*10.))*10.)
  i4=nint((scn*100.-int(scn*100.))*10.)
  elev=e(i1)//'.'//e(i2)//e(i3)//e(i4)
endif

return
end
```

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